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DIAMETER-LIMIT CUTTING in Appalachian Hardwoods: *BOON or BANE?*

by G. R. Trimble, Jr.

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BOON OR BANE?

DIAMETER-LIMIT CUTTING is widespread and is applied in a great many ways, often without appreciation of its advantages and disadvantages and without an understanding of its effects on subsequent stand development. Although the technique has advantages, unless applied carefully, it can have long-lasting adverse effects on sawtimber production. The latest results of studies of diameter-limit cutting on the Fernow Experimental Forest, near Parsons, W. Va., shed additional light on its use as a silvicultural tool for sawtimber production.

Varied Applications

When diameter-limit cutting is intended as a valid forestry measure, an attempt is made to set a diameter that will result in harvesting only trees that are more-or-less financially mature. Theoretically at least, a well-stocked stand of trees is left to occupy the site and to provide for similar future cuts at more-or-less equal intervals on a sustained-yield basis.

Diameter-limit cuts are sometimes applied as one-shot treatments. In such cases, the implied intention is to adopt a more intensive type of forest practice in the future. Such cuts may be made to recover the purchase price of forest land in one cutting, or to condition a second-growth stand that contains a number of large old residuals from a previous cutting. The latter application—to harvest the residuals—is typical in Appalachia.

Another use, and perhaps the most common one, is to set a diameter limit that will roughly separate the trees it pays to harvest from those on which the operator loses money. A limit thus set both facilitates appraisal work and guides the fallers in leaving submarginal trees. In this application, many hardwood sawtimber operators use a 14-inch stump diameter limit. This method of cutting is almost always applied on someone else's land—or if on one's own land, is applied through ignorance—with little or no thought to long-term value or productivity.

Past Research

A number of observers have written about the results of diameter-limit cutting, based on theoretical grounds and on short-period research.

Hutnik (1958) made a 5-year report on diameter-limit cuts made in mixed hardwood stands on medium sites on the Fernow Experimental Forest. He said that the big advantage of diameter limit cutting is simplicity of application, but that cutters still require the same supervision as on a marked stand. Another advantage is that returns per unit volume can be greater, because—unless the diameter is set very low—no low-value small trees are handled. Hutnik pointed out that,

> both of these advantages are most important in the first cut. Thereafter, the disadvantages begin to show. Compared to the selection system, growth following a diameter-limit cut is considerably less. Dense young stands are not thinned; areas supporting large trees are completely cut-over; dying small trees are not salvaged; trees of the highest vigor tend to be cut first, while trees of low vigor remain in the stand; slow-growing species tend to be left and fast-growing species cut; the smaller, low-quality trees are left; and there is no control over reproduction. Thus, not only is the total amount of growth less, but also the value per unit of growth is less.
>
> Some of the disadvantages already cited could be resolved by changes in the method of management. A flexible diameter limit could be made where desirable trees just above the limit are left and undesirable trees below the limit are cut. Also the diameter limit could be varied with species, site and stand size. But every step taken in this direction increases the amount of management and more closely approaches the selection system.

Blum and Filip (1963), writing about diameter limit cutting in northern hardwoods on the Bartlett Experimental Forest in New Hampshire, came to conclusions similar to those of Hutnik.

Trimble (1961), from a 10-year study of a diameter-limit cut on an excellent site in West Virginia, reached similar conclusions and observed that special caution should be exercised in judging the early results of diameter-limit cutting. He felt that it is unlikely the effects of this type of management will be fully expressed until at least two cuts have been made.

Smith's (1962) discussion of selection thinning bears on the effect of diameter-limit cutting on the stand. He writes (parenthetical comments are mine):

> In selection thinning, dominant trees are removed in order to stimulate the growth of the trees of the lower crown classes. (This is, in effect, the way diameter-limit cuts work). The same kind of vigorous trees that are favored in crown and low thinning are the very ones that are likely to be cut in selection thinning. It is obvious then that selection thinning is suitable only for rather limited purposes and, if not carefully used, readily degenerates into high-grading . . . Selection thinning, by removing numerous dominants, may reduce the investment more but it usually reduces the growth in value as well . . . Selection thinnings have little place in hardwood management except as initial corrective action in elimination of rough dominants from young stands. (This corresponds to setting diameter-limits to harvest old residuals).

Hart (1964), writing of his 9-year experience with diameter-limit cutting in mixed hardwood—spruce-fir plots in Maine, said: ". . . Diameter-limit cutting results in uneven stocking. And it tends to remove many vigorous trees above the limit while leaving defective and poor-vigor trees below the limit."

FERNOW RESEARCH

Data recently available from areas on the Fernow Experimental Forest cut one and two times by the diameter-limit method, when compared to data from selection-cut and clearcut areas, provide the basis for confirming, modifying, and extending earlier observations on this method of cutting. This should facili-

tate making more rational judgments about using diameter-limit cutting for the production of sawtimber.

The diameter-limit-cut areas had minimum cutting diameters between 15.5 and 17.0 inches and averaged 16.6 inches. The clearcut stands were harvested to 5 inches d.b.h. In the selection-cut stands, individual trees were marked for cutting throughout the d.b.h. range above 11 inches, so trees below sawlog size were ignored. Cuts were 15 to 20 years apart for the diameter-cut areas and about 10 years apart for the selection-cut areas.

Stand Composition

The distribution and density of the tree canopy after cutting affect the relative abundance of tolerant species versus intolerant species among stems of reproduction. One of the most frequently observed disadvantages of diameter-limit cutting is that it provides no control of spacing and so results in a clumpy stand with clearcut and partially-cut areas interspersed with overly-dense areas. This was the situation on all of the diameter-limit stands studied on the Fernow.

Where a mixture of hardwood species exists, such cutting favors reproduction of intolerant species in the large openings and tolerant species in the lightly-cut areas. In this respect, such cutting should be intermediate between single-tree selection cutting and clearcutting; the former should result in a higher proportion of tolerant species, and the latter should produce more intolerants. Observations of reproduction 7 to 20 years after logging on areas cut in all three ways on the Fernow showed this to be the case (table 1).

All three types of cutting resulted in abundant and well-distributed reproduction of commercial species (Trimble and Hart 1961 and Wendel and Trimble 1968).

If lower diameter limits had been designated for cutting (for example, 14 inches d.b.h. instead of 17 inches), we would have expected to find more intolerants in the reproduction and, probably, more of the new stems would have been sprouts.

Another disadvantage of diameter-limit cutting: Because small-size stems are ignored, species composition is not controllable

Table 1.—*The effect of cutting practice on the proportions of tolerant versus intolerant reproduction*

Type of cutting	No. of areas	Total acreage	Site index (for oak)		Number of 1- to 5-inch stems in—		Stump sprouts as a proportion of total reproduction
			Range	Average	Intolerant[1] species	Tolerant[2] species	
	No.	*Acres*	*Ft.*	*Ft.*	*Weighted Pct.*	*Weighted Pct.*	*Pct.*
Clearcut	9	110	61 - 77	70	37	27	58
Diameter-limit	5	151	59 - 75	69	18	62	18
Selection	7	198	59 - 82	71	5	78	18

[1]Red oak (*Quercus rubra* L.), *yellow-poplar* (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), white ash (*Fraxinus americana* L.), black locust (*Robinia pseudoacacia* L.), sassafras (*Sassafras albidum* (Nutt.) Nees).
[2]Beech (*Fagus grandifolia* Ehrh.), sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.).

below the minimum cutting diameter. Undesirable species, such as beech, may gradually increase in number until they form the bulk of the stand growing across the cutting threshold. (No such trend is yet discernible on the Fernow.)

Quality

Two measures of quality were used to compare results of diameter-limit cutting with selection cutting: (1) proportion of stand volume in cull trees, and (2) log quality of the stand.

(Not enough cuts have been made for scaling defects to be correlated with the cutting system. However, in the diameter-limit system, the fact that the small poorly-formed and partly-rotten trees are left to grow predestines future cuts to higher scaling deductions than in selection cutting.)

Cull Trees.—In general, the custom is to kill culls down to the minimum diameter limit considered for cutting. This means that some sawtimber culls are usually left where diameter limits are above 11 inches.

In applying the selection system of sawlog management on the Fernow, culls above 11 inches d.b.h. were killed. In the diameter-limit cutting areas, only those culls were killed that were larger than the minimum cutting diameter of 17 inches.

The data taken after the first cuts showed that diameter-limit cutting reduced the original cull tree volume 85 percent (obviously most of the original cull-tree volume was in trees above 17 inches d.b.h.). The selection cutting reduced cull tree volume by 99 percent (table 2).

These figures are merely indicative and do not necessarily characterize diameter-limit cuts. To illustrate the possible extremes, a 12-inch-stump diameter cutting would take all sawtimber-size cull trees; in contrast, in a stand cut to a 17-inch limit where all original sawtimber cull trees were between 11 and 17 inches, no culls would be killed.

Grapevine damage is a big factor on medium and better sites when stands are cut heavily. Grapevines are intolerant; and once cut out of trees, they do not grow back unless the stand is opened up drastically. Under the selection system, stand improvement

Table 2.—*Cull tree volume in the sawtimber-stand*

Method of cutting	Total acreage	Cull tree volume in sawtimber trees		Reduction
		Before cutting	After cutting	
	Acres	*Pct.*	*Pct.*	*Pct.*
Diameter-limit	237	8.5	1.3	84.7
Single-tree-selection	179	15.0	.1	99.3

measures generally include cutting grapevines, and in most cases they are inhibited from regrowing by the shade of the canopy. However, under diameter-limit cutting, where big holes are left in the canopy and where, customarily, little stand improvement is done, grapevines proliferate and may reduce future timber growth rates and log quality.

Log Quality.—Log grade indicates the relative quality of the lumber in the tree. Since hardwood values are so highly correlated with timber quality, log grades strongly reflect profitability. Log grades 1 and 2 (Ostrander and others 1965) are the money makers, and they provide a useful yardstick by which to judge the success of a forestry practice.

On the Fernow, log grades were sampled on several areas to determine the effects of both diameter-limit and selection cutting on the proportion of the different log grades (table 3). In interpreting the meaning of grade changes, the conditions of the stands and nature of the treatments must be kept in mind. All of the stands were vigorous, middle-age, second growth, and contained varying proportions of old large residuals.

In the diameter-limit cutting, the diameter limits were so set (at 17 inches d.b.h.) that the first cut took most of the old residuals and little else. Many of these old trees were partly defective, and this resulted in low average grade yield in the first cut.

The second cut in these stands took the faster-growing trees of the second growth. These were good quality trees with a lot of log-grade-1 material (the minimum-sized tree that can have a

Table 3.—*Proportion of sawtimber volume in the better log grades*

Area no.	Size	Proportion of sawtimber in log grades 1 and 2					
		Stand after cutting			Harvested trees		
		1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd
	Acres	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pc*
		DIAMETER - LIMIT CUTTING					
27A	34	—	34	—	—	58	—
9A	53	7	42	—	30	58	—
8A	5	19	23	—	47	60	—
9	81	8	44	—	33	58	—
Weighted average		8	41	—	32	58	—
		SELECTION CUTTING					
WS5A	78	27	53	—	6	38	—
WS5B	12	38	56	—	12	35	—
7C	20	—	51	—	—	51	—
19B	11	30	45	—	30	52	—
8C	5	24	40	58	26	34	4[illegible]
Weighted average		28	52	58	10	41	4[illegible]

grade 1 butt log is 16 inches d.b.h.). Grade yield of the second cut was thus much higher than the first; second cuts averaged about 58 percent in grades 1 and 2 logs compared to 32 percent for the first cut. We predict that the next cut will show a drop in grade from the second cut. This cut will be composed of (1) slow-growing individuals of intolerant species that have passed many years in partly submerged positions (and, therefore, will be more subject to degrade through epicormic branching) and (2) of slower-growing species, the beech component of which will be low grade (Trimble 1965).

The selection-cut stands, because they were cut on a different basis, exhibited a different pattern of grade development. While the diameter-limit cuts were in essence high grading, the selection cuts built up stand grade by taking the poor trees first. After the second cut, the residual selection stands averaged 52 percent in log grades 1 and 2, while the diameter-limit stands averaged only

41 percent in these grades. Part of the difference is due to the fact that more large trees were left in the selection stands.

Grade yield of the selection-cut areas improved steadily, from 10 percent in log grades 1 and 2 for the first cut to 41 percent for the second cut. However, after two cuts, the selection-cut yield still does not equal the yield of 58 percent in log grades 1 and 2 from the diameter-limit second cut.

We predict that grade yields of the third cuts under the two systems will be more nearly equal; and that, in subsequent cuts, the selection system will provide higher grade yields. (Moreover, by then, a real difference in scaling deduction should be showing up in favor of the selection system.)

Growth

Diameter-limit cutting contains three potential sources of loss of merchantable timber growth: (1) loss in cull-tree volume and in volume of scaling deductions in merchantable logs (discussed previously), (2) mortality of trees below the cutting diameter, and (3) loss due to understocking.

Diameter-limit cutting makes no provision for salvaging dead trees below the designated cutting diameter. Sawlog-size trees that die before they reach the minimum cutting diameter are lost to harvestable growth; in comparison, most of this growth is harvested in selection cutting. The situation is accentuated when species that mature at small size make up an appreciable part of stands. Cutting to a higher uniform minimum diameter means that most of the volume of such species is lost.

Cutting stands below full site occupancy is another source of growth loss. Because of the inherent lack of control over density and spacing, this can easily happen in diameter-limit cuttings. Our growth data seem to indicate that this is happening on the Fernow diameter-cut study areas (table 4).

It appears that these stands were cut well below full site occupancy for both board foot and cubic foot growth; the growth rate for the first 5 years after logging was below the annual rates for longer measuring periods, indicating that, as stocking increased, growth rate increased. The growth rate ratios indicate

Table 4.—*Growth of sawtimber*

Area	Oak site index	Diameter limit	Basal area after 1st cutting in trees over		Annual per acre growth in 1st 5 years of study period		Basal area at end of 5 years in trees over		No. of years from 5th year to end of period	Annual per acre growth from 5 years to end of study period		Annual growth for 1st 5 years as percent of growth in the second-period	
			5 inches d.b.h.	11 inches d.b.h.			5 inches d.b.h.	11 inches d.b.h.					
No.	*Ft.*	*In.*	*Ft.*	*Ft.*	*Bd. ft.*[1]	*Cu. ft.*[2]	*Ft.*	*Ft.*	*Yrs.*	*Bd. ft.*	*Cu. ft.*	*Bd. ft.*	*Cu. ft.*
DIAMETER-CUTTING AREAS													
27-A	70	16.5	57	23	277	54	66	31	13	377	69	73	78
27-B	66	16.5	64	26	275	53	73	35	14	406	70	68	76
8-B	78	15.5	42	22	349	61	54	32	15	534	90	65	68
26-B	65	13.5	66	14	239	50	75	23	15	456	—	52	—
SELECTION-CUTTING AREAS													
8-C	78	—	54	41	467	87	70	55	15	369	72	127	121
16-A	77	—	90	50	477	51	97	65	12	577	85	83	60
8-C	78	—	58	42	551	95	76	58	15	459	81	120	117
13[3]	76	—	102	68	494	87	95	65	15	329	57	150	153
21[3]	74	—	93	43	251	58	86	40	15	272	48	92	121

[1]Measured by the International ¼-inch kerf rule to an 8-inch top d.i.b. in trees over 11.0 inches d.b.h.
[2]Measured to a 4-inch top d.i.b. on all trees over 5.0 inches d.b.h.
[3]These two stands were cut lightly several times in the first 5 years; this accounts for the fact that basal areas are lower after 5 years than after the first cut.

that board foot growth was reduced more than cubic foot growth.

When the same type of comparison was made for a number of selection cut areas, i.e., growth comparisons between the 5-year post-logging period and the longer later period, on the average, no growth increase occurred. This adds further proof that the diameter-limit cut areas were understocked. (The decreased growth in the second period for the selection cut areas is probably related to increasing stand age and reduction of ingrowth rather than to a stocking factor.) A comparison of the post-cutting basal areas between the two types of cutting shows that stocking for diameter cutting areas was much less than for selection cutting areas (table 4).

We conclude that diameter-limit cutting, as practiced on the study areas, has resulted in a growth loss after the first cutting that will never be made up. It is logical to expect that this same type of growth loss will be repeated after similar diameter-limit cuts.

Sawlog growth is undoubtedly quite low for a long period after the common 12- and 14-inch-stump diameter cuts. This results in either an extremely long period between profitable cuts or subsequent harvests of small trees with low-grade logs, or probably both.

Eventually, the Fernow diameter-limit cuts should provide—for one specified kind of diameter-limit cutting—a sawlog growth comparison with selection-cuts where defective trees are eliminated, potential mortality is recovered, and residual sawtimber stands more fully occupy the site. Because of differences between the original stands in species composition, in cull tree volume, and in stand structure, two more cuts will probably be required to establish growth rates representative of the two cutting practices.

Value of Cuts and Residual Stands

In general, cutting big trees results in low unit costs of logging, if the trees are not too big for easy handling and if the harvests are heavy enough to minimize the impact of such fixed

costs as road work and transporting equipment. Also, other things being equal, big trees are more valuable because they have higher grade and produce better lumber. Thus cutting to a high minimum diameter is characterized by high monetary returns per thousand board feet. This has been true with 17-inch diameter-limit cutting on the Fernow. If the minimum diameter was set at 20 to 24 inches on the better sites, the return per thousand board feet would be even higher.

On the other hand, very heavy per-acre cuts (such as 14-inch stump-diameter cuts)—which take most or all of the merchantable trees, but not the submarginal ones—are characterized by returns that are higher per acre, but lower per thousand board feet.

Initial selection cutting in unmanaged sawtimber stands, unless deliberate high grading, usually returns less per thousand board feet and less per acre than diameter-limit cuts. This is especially true when the costs for selection marking are considered.

These are generalized relationships that apply to first cuts in average unmanaged sawtimber stands. Many factors may cause them to vary including the minimum diameter limit; the marking guides used for selection cutting; stand variables such as species composition, distribution of stem sizes, stand volumes, and cull-tree frequency; and whether or not stand improvement treatments are subsequently applied.

Theoretically, after a number of cuts, the relative value of the harvests under the two practices can be expected to change. Because of stand deterioration under the usual diameter-limit cutting and stand improvement under a good selection system, the value of future cuts should be greater under the selection system.

Conclusions

For a number of reasons, which have been discussed in this paper, diameter-limit cutting is not recommended as a method of repeatedly harvesting hardwood stands. When diameter limits are set low, periods between cuts are too long or only small trees are available in the recuts. When the diameter limit is set

high, the potential silvicultural disadvantages of the system are postponed, that is, a long period of time will pass before they show up. This is especially true if the diameter limit is set to conform with stand conditions and to approximate financial maturity.

Another drawback to diameter-limit cutting is that, with many crews, supervision costs are high. This is especially true if a high minimum diameter is designated.

A number of modifications can be made in diameter-limit cutting to improve its performance and soften the impact of its poor features. These include killing culls below the minimum diameter, different diameter limits for different species to conform to their physiological and financial maturity sizes, and setting diameter limits based on stand inventories so as to leave a residual stand that fully occupies the site. However, as pointed out by Hutnik, when these steps are taken the advantages of diameter-limit cutting, that is, cheapness and ease of application, are partially lost.

In many cases, cutting to a diameter limit has immediate short-range economic advantages. Moreover, if it is done right—such as making only one diameter-limit cutting and setting the limit high so as to remove only old residuals—it should have no adverse long-range silvi cultural effect on the stand.

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Production & Germination of PAPER BIRCH SEED and its Dispersal into a Forest Opening

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by John C. Bjorkbom

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KNOWLEDGE of the seed-crop characteristics of paper birch (*Betula papyrifera* Marsh.) is essential to the success of carefully planned silvicultural measures aimed at the natural regeneration of this species. In general, we know how much seed is produced, when it is dispersed, and what its germination characteristics are *(2, 11, 12)*. But more specific information about all three factors is needed to provide silviculturists with a sound basis for developing methods of regenerating paper birch that forest managers can apply successfully.

In 1964, the Northeastern Forest Experiment Station began a 3-year study of the production, dissemination, and germination of paper birch seeds. Results of this study have emphasized the need to consider seed quality as well as germinative characteristics in evaluating seed crops. It has also shown that, in the stands surrounding a clearcutting, most of the seed is dispersed within these stands and that the proportion falling into the clearcutting diminishes rapidly as the distance from the forest edge increases.

The Study Area

The study area was located on the Penobscot Experimental Forest near Orono, Maine. It included a clearcut area 7 chains square surrounded by paper birch seed trees in a forested strip 1 chain wide. The bordering forest, about 75 years old, consisted largely of poletimber-size paper birch and red maple (*Acer rubrum* L.) with a scattering of other hardwoods and softwoods. Average height of the paper birch trees was about 60 feet.

Paper birch trees 5.0 inches in diameter and larger were considered as seed trees. The number of these trees surrounding the clearcutting varied. There were about 149 per acre in the north stand, 107 per acre in the east and west stands, and about 27 per acre in the south stand.

Methods

To estimate the proportion of the paper birch seed crop dispersed at varying distances from each side of the clearcutting, seed traps were located in two strips that bisected opposite sides of the study area. One strip was oriented approximately north and south, the other east and west. These strips were 1 chain wide and 9 chains long, and were divided into 9 blocks of equal size (fig. 1). On each strip, the two end blocks were in the forest stand; the remaining seven blocks were in the clearcutting.

Three small seed traps were randomly located within each block, a total of 51 traps. These traps, 6.5 inches in diameter, were mounted on posts about 3 feet above the ground. They were used only for estimating the number of paper birch seeds dispersed into the clearcutting.

To provide a greater number of seeds for estimating production, germination, and dispersal, four larger traps (16 inches square) were placed on the ground in the residual stand 1 chain from the edge of the clearcutting. One of these traps was placed on the back edge of each end block on both strips.

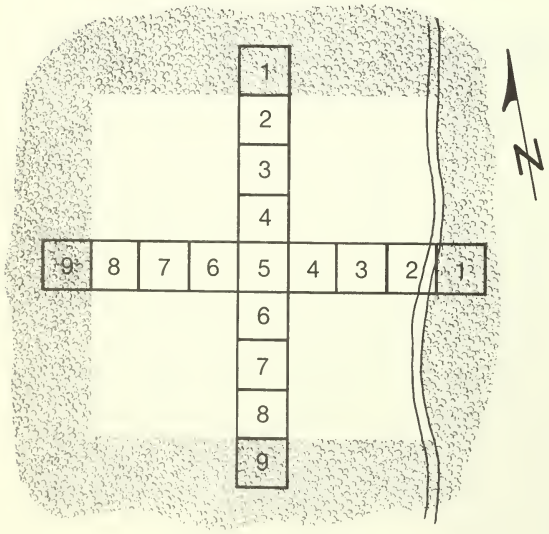


Figure 1.—The two strips of blocks were laid out to bisect opposite sides of the clearcutting.

Seed collections were made weekly from August through November, the period of greatest seedfall *(2)*. Traps were not visited from the beginning of December until spring when the final collection was made.

Immediately after each collection, the paper birch seeds were counted and sorted into one of three seed quality classes: (1) empty seeds that were weeviled or had empty seed coats, (2) discolored seeds with brown or black edges or spots, and (3) good seeds.

All seed collections were carefully marked to show the date of collection, trap number, and quality class. They were then stored in paper envelopes at about 35°F. until after the final seed collection in the spring, when germination tests were made. Whether or not the varying lengths of storage (2 to 10 months) had an unequal effect on germination is not known.

Germination tests were conducted in a darkened germinator set to operate at about 92°F. for 8 hours during the day. Room temperature during the night averaged about 68°F. After slow cooling, the germinator reached this temperature.

Seed Production

Seed production varied among the three seed years and among the stands adjacent to the clearcutting. Production estimates based on the number of seeds trapped within the forest stand ranged from a low of 0.7 million seeds per acre in 1964 to a high of 9.8 million seeds per acre in 1966 (table 1). Paper birch seed production as high as 36 million seeds per acre has been reported *(11)*, although these very heavy crops occur only about once in every 10 years *(4)*. On the other hand, reasonably productive seed years occur about every other year *(2)*.

The seedfall was greatest in the north and east stands, least in the south and west stands. Since the number of female catkins per tree was estimated to be roughly equal in all stands for each year of record, stand composition probably accounts for much of the difference. The south stand had the fewest

Table 1.—*Paper birch seed production by quality class, stand, and seed year*

Seed year	Stand	Quality class			Number per acre
		Good	Discolored	Empty	
		Pct.	*Pct.*	*Pct.*	*Million*
1964	North	53	13	34	2.4
	South	63	15	22	0.7
	East	61	11	28	1.6
	West	69	25	6	1.0
	Average	59	15	26	1.4
1965	North	69	12	19	5.4
	South	66	19	15	1.7
	East	65	12	23	5.2
	West	79	11	10	3.1
	Average	69	13	18	3.9
1966	North	79	14	7	9.8
	South	83	13	4	2.6
	East	86	9	5	9.4
	West	85	13	2	3.1
	Average	83	12	5	6.2

seed trees. The west stand, with the same number of seed trees as the east stand, had a considerable number of hemlocks whose crowns presumably deflected or retained many seeds that otherwise would have fallen into the seed traps. The prevailing winds might also have affected seed distribution. Coming from the southwest, these winds might have blown seeds beyond the traps for the south and west stands.

To put seed production in its proper perspective, it must be considered in terms of seed quality. In this study, poor-quality seeds (discolored and empty combined) accounted for 14 to 47 percent of the total seed crop. Discolored or empty seeds result from a variety of causes that can occur from the start of flowering in the spring until bud formation in the fall. Adverse weather conditions, poor pollination, failure of fertilization, diseases, and insects all play a part. Whether or not seed quality depends on the size of a seed crop is not entirely clear. But in

this study, high seed production in 1966 was associated with a substantial reduction in the proportion of empty seeds.

Germination

Germination tests were made of the paper birch seeds from the larger traps within the forest stands to estimate the effects of seed year, seed quality, and time of dispersal on seed viability. Both germinative capacity and germinative energy of the seeds were determined for each seed-quality class.

Germinative capacity is the percent of seeds germinating, regardless of time *(12)*. For seeds of good quality, this was better in the more productive seed years and better for seeds dispersed in late fall and winter (table 2). Although there were too few discolored seeds for a completely reliable test, the results suggested that their germinative capacity was lower than for good seeds.

Germinative energy is the percent of seed germinated at the time the trend of germination reaches its peak *(12)* and the germinative energy period terminates with the rapid and constant decrease in daily germination *(10)*. Because it accounts for rapidity of germination, germinative energy is probably a better measure of the worth of a seed crop than is germinative capacity.

Table 2.—*Germinative capacity of paper birch seed by seed year and month of dispersal*

Month of seed dispersal	Seed year		
	1964	1965	1966
	Pct.	*Pct.*	*Pct.*
Aug	27	48	43
Sep	34	55	45
Oct	40	69	69
Nov	63	67	72
Dec to spring	77	65	68
Average	49	65	64

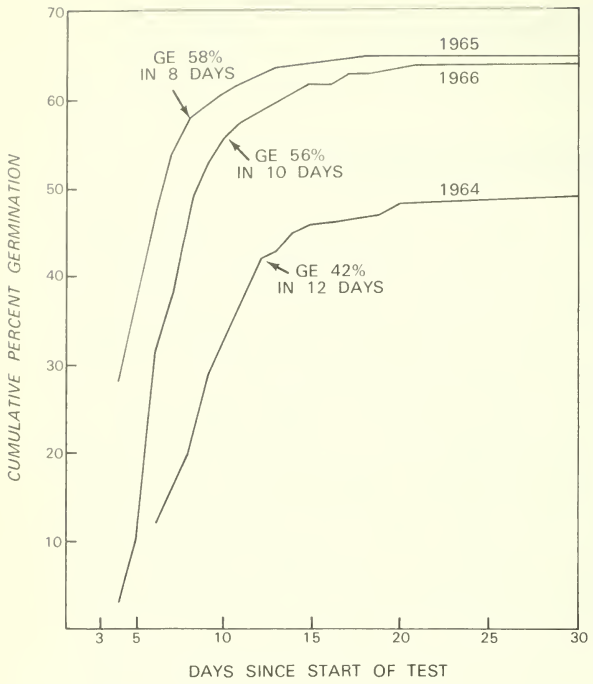


Figure 2. — Germination begins sooner and proceeds more rapidly in the more productive seed years. The germinative energy (GE) and the end of the GE period are indicated.

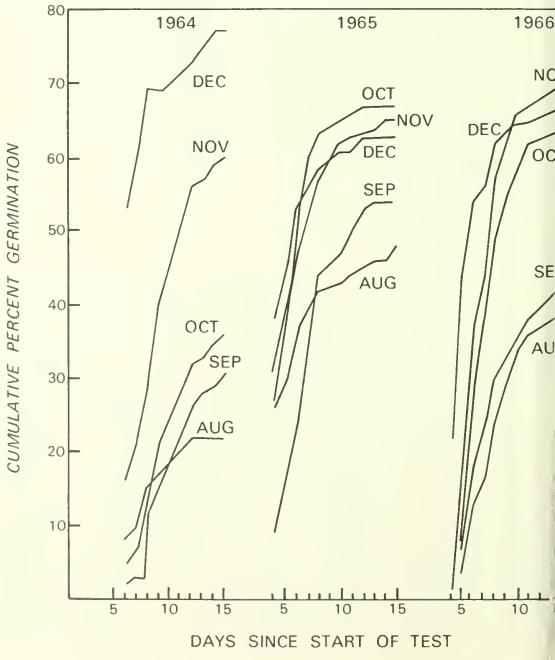


Figure 3.—Germination is faster and greater for seed dispersed in late fall and winter.

Germination tests showed that, in the better seed years, the germinative energy of good seed not only reaches higher levels than the poor-quality seed, but germination begins sooner and proceeds more rapidly than in less productive seed years (fig. 2). Germinative energy of the seed also varies by month of dispersal: as the dispersal season progresses, the germinative energy improves (fig. 3). These are important factors in regeneration, because seedlings that germinate long before the onset of summer heat and drought have a better opportunity for survival. Limited tests of discolored seeds suggest that these seeds germinate at a much slower rate.

Time of Dispersal

In general, relatively small amounts of seed fall early in the dispersal period. As the season progresses, seedfall increases

Table 3—*Dispersal of the paper birch seed crop by month of dispersal, stand, and year*

Stand	Percent of total seedfall					Total
	Aug	Sep	Oct	Nov	Dec - spring	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
.....North	5	8	47	24	16	100
South	7	39	17	29	8	100
East	21	43	15	19	2	100
West	1	9	12	45	33	100
Average	9	22	28	27	14	100
.....North	7	15	27	46	5	100
South	17	12	50	17	4	100
East	7	10	51	28	4	100
West	9	9	54	18	10	100
Average	11	12	43	29	5	100
.....North	10	10	30	17	33	100
South	12	15	42	26	5	100
East	6	13	11	68	2	100
West	4	10	50	30	6	100
Average	8	12	27	38	15	100

rapidly to a peak and then decreases sharply as the end of the dispersal period approaches.

The proportion of the seed crops dispersed in any month varied by forest stand and by year in this study (table 3). But for all stands combined, most of the paper birch seeds fell in October and November. Time of dispersal did not appear to depend on the size of the seed crop.

Seed Dispersal Pattern

In general, most of the paper birch seed crop fell within the forest stand (fig. 4). In this study, and for sampling areas of the same size, 3.5 to 7.1 times as much seed fell in the forest as in the clearcut area.

As distance from forest edge increases, the amount of seed decreases rapidly. To describe this pattern of seed dispersal, a regression analysis was made of the seedfall on distance from

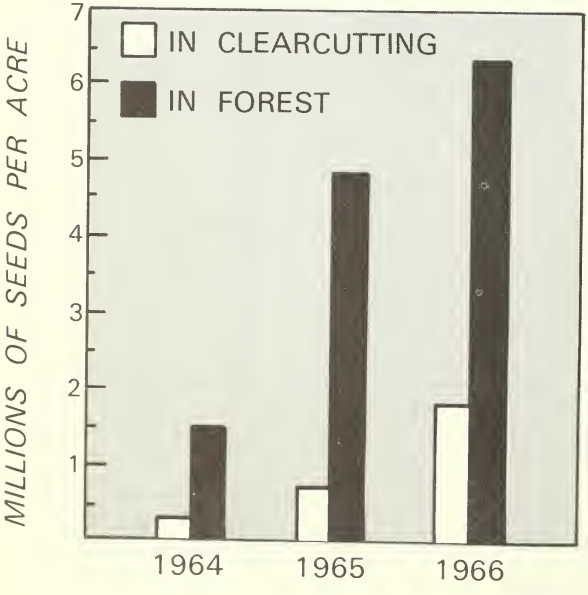


Figure 4. — Most paper birch seed falls within the forest stand rather than in an adjacent clearcutting.

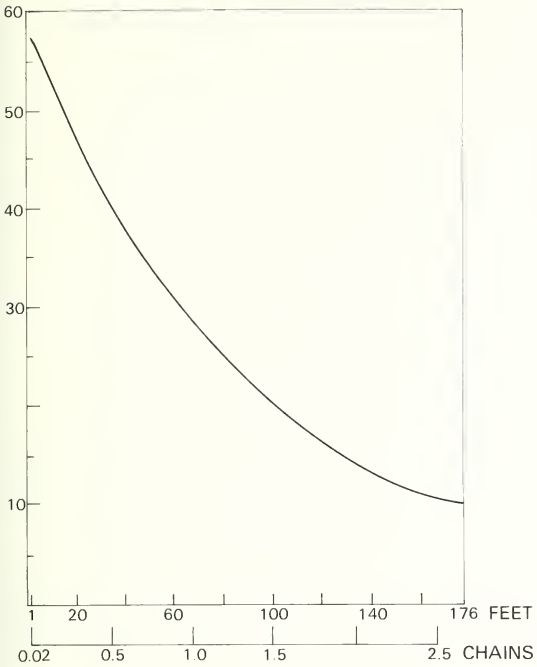


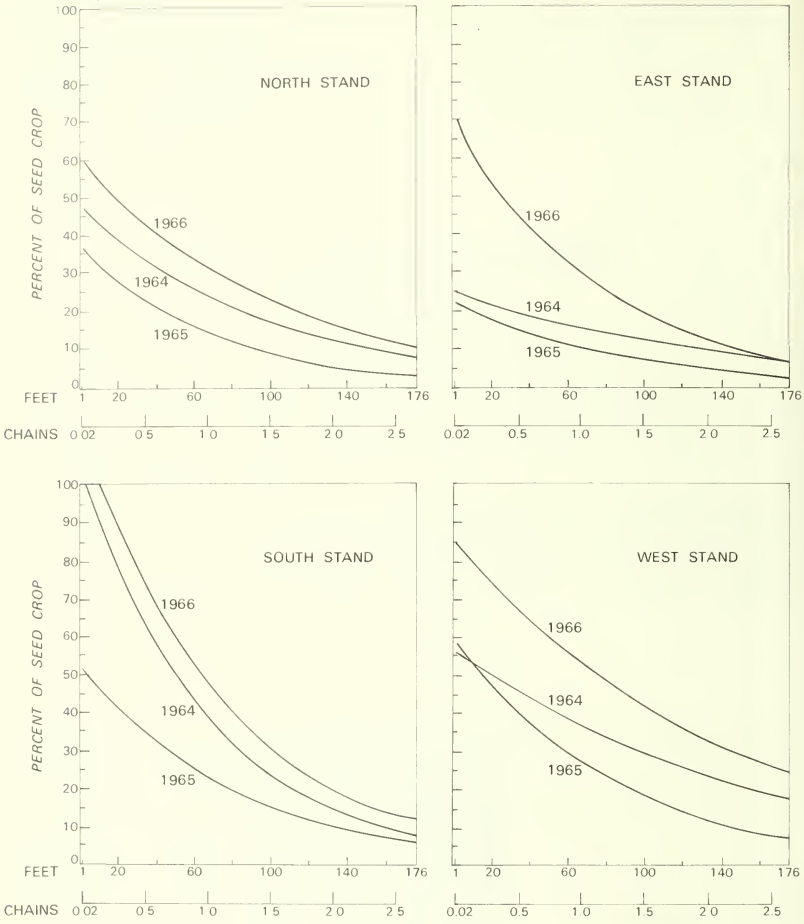
Figure 5.—The percent of the seed crop dispersed into the clearcutting drops off rapidly as the distance from forest edge increases. In this case, the coefficient of determination (r^2) is 0.62.

forest edge. The seedfall at any distance from this edge was described as a percentage of the seedfall within the forest stand. Regression equations showing the seed-dispersal pattern for each of the four stands in each of three seed-years were then derived by least squares. An additional equation for all stands and all years combined was also obtained.

To illustrate the average dispersal pattern, consider the curve (fig. 5) for the combined data. Adjacent to the forest stand, the seedfall amounted to 58 percent of that within the stand. As the distance is increased to a maximum of 176 feet, only an estimated 10 percent might be expected to fall. Similar curves for each stand and seed-year (fig. 6) emphasize the variability that might be expected.

The coefficient of determination (r^2) of 62 percent for the combined data indicates that distance from forest edge presents a reasonable picture of expected seed dispersal into a clearing.

Figure 6.—The proportion of the paper birch seed crop dispersed various distances into the clearcutting varied by forest stand and by seed year.



In only three individual cases — the east stand in 1964 and 1965, the south stand in 1965 — was distance not a good estimator of seed distribution into the clearing (table 4). Apparently some unmeasured factor influenced distribution in these cases. However, seedfall was strongly associated with distance, and these curves can be useful in predicting amounts of seed that might be expected at varying distances from the forest edge.

In general, the tendency for the amount of paper birch seed

Table 4.—*Coefficients of determination (r^2) for distance from edge of clearcutting and percent seedfall*

Forest stand	Coefficients of determination		
	1964	1965	1966
	Pct.	*Pct.*	*Pct.*
North	70	71	83
East	29	39	98
South	64	53	80
West	78	86	61

to decrease sharply with an increase in distance from the forest edge is similar to that reported for other species.

The seedfall of yellow birch (*Betula alleghaniensis* Britton) at the edge of a forest opening was reported to be 6 times greater — and sugar maple (*Acer saccharum* Marsh.) 4 times greater — than the seedfall of these species 5 chains into a clearcutting *(1)*. The effective dispersal distance of *Betula verrucosa* Ehrh. and *Betula pubescens* Ehrh. was established as twice the height of the seeding trees *(8)*. Similar results have also been reported for some softwoods *(3, 6, 7, 9, 13)*.

Silvicultural Implications

The seed crop data presented here have some important silvicultural implications in the regeneration of paper birch stands. By using these data, we can make a better evaluation of the seed crop in terms of dispersal distance, seed quality, and germination characteristics. These factors, combined with an estimate of how much seed is required for satisfactory regeneration, will aid in determining the type of regeneration cutting to be made.

What constitutes an adequate quantity of seed depends on the probability of seedling establishment; and a single estimate to cover all situations is not practical. The paper birch seed

production and germination data reported here, added to that already published *(2),* will help to provide reasonable estimates.

Since one-half or more of the seed crop is dispersed in October and November, all site preparation aimed at regenerating a paper birch stand should be completed by that time. By doing so, the seeds will be more likely to find a receptive seedbed and soon be protected and stratified by a snow cover. Also, since germinative energy is greater for seed falling in these months than it is earlier, seed collections should be made at this time.

Work done with *Betula verrucosa* and *Betula pubescens (8)* indicates that a seedfall of 100 to 200 filled seeds per square meter may be required if a maximum number of seedlings is to be produced by natural regeneration without special site preparation. This is equivalent to an average of 600,000 viable seeds per acre or, adjusted for seed quality, a total of 630,000 to 800,000 seeds per acre. Using this estimate, we can determine fairly easily the effective seed-dispersal distance for seed crops of varying size.

To illustrate: first read the percent of total seedfall for various distances from the curve in figure 5. In practice, the curve selected should be the one that comes closest to the user's situation. Multiply the estimated seed crop by the percent factor to determine the number of seeds per acre at the selected distance. Then plot these data as in figure 7. This figure shows that a seed crop of 2 million seeds per acre would be effectively dispersed a distance of 0.50 to 0.75 chains from the forest edge. A seed crop of 8 million seeds per acre would be effectively dispersed slightly over 2.5 chains.

If paper birch is to be regenerated in clearcut strips, then figure 7 can be used to estimate the width of strip that will be effectively seeded. Assuming equal dispersal from both sides of the strip, crops of 2 million and 8 million seeds per acre would effectively seed strips 1.0 to 1.5 chains wide and about 5 chains wide respectively.

These estimates are conservative because they apply to undisturbed seedbed conditions only. Forest managers should adjust these estimates to reflect the influences of seedbed condition,

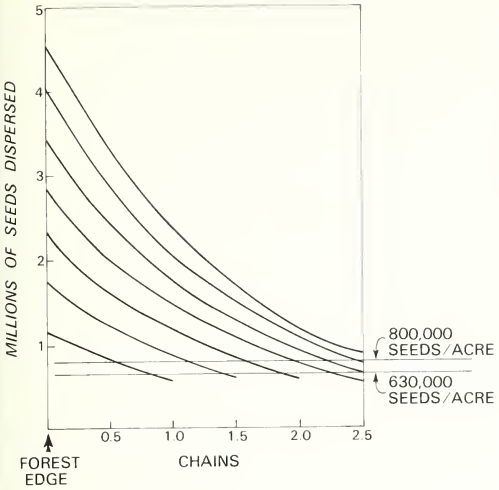


Figure 7. — Distances at which adequate seed is dispersed for seed crops of different size to regenerate a new paper birch stand on undisturbed seedbeds.

topography, and exposure to sunlight and shadow. Guidelines for modifying these influences are given in the Birch Symposium Proceedings *(5)* and in the Silvicultural Guide for Paper Birch in the Northeast *(4)*.

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Response of *Fusarium solani* to Fluctuating Temperatures

by Keith F. Jensen
and Phillip E. Reynolds

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MANUSCRIPT RECEIVED FOR PUBLICATION 8 MARCH 1971

Response of *Fusarium solani* to Fluctuating Temperatures

AS PROGRAMMED incubators have become available, several researchers have attempted to evaluate the effect of temperature and temperature change on the growth of fungi (*1, 4, 7*). Conflicting conclusions have been reported about whether temperature fluctuation itself has an effect on fungus growth. This point must be clarified before the question of whether growth of an organism in a fluctuating temperature regime can be predicted from growth data collected in constant temperature studies.

The purpose of our study was to measure growth under a range of constant temperatures and under a series of fluctuating temperature regimes, and to determine if growth in the fluctuating temperature regimes could be predicted satisfactorily from the growth data collected in the constant temperature experiments. Growth was measured on both agar and liquid culture to determine if the reported differences were due to substrate instead of temperature treatments.

MATERIALS AND METHODS

Fusarium solani (Mart.) App. & Wr. emend Synd. & Hans. was grown in an incubator controlled by a cam-type temperature programmer for both the constant and fluctuating temperature treatments. For the fluctuating temperature experiments, the programmer was equipped with a cam that caused the temperature in the incubator to change in a linear manner from one temperature extreme to the other and back again during a 24-hour period. The constant temperature treatments were 15, 20, 25, 30, and 35°C. The fluctuating temperature treatments were 25 ± 3, 25 ± 6, 25 ± 9, 30 ± 3, 30 ± 6, and 30 ± 9°C.

Six isolates of *F. solani* were grown at each temperature treatment. Five of the isolates, F1M, F2P, F3Y, F5P2, and F6P3, were collected from cankers on hardwood trees; the sixth, F4S, was isolated from soil. F4S may also be parasitic on hardwood trees, even though it was isolated from soil.

Liquid and agar cultures were used in all experiments. The liquid medium contained: sucrose, 10 g.; $NH_4H_2PO_4$, 2 g.; KH_2PO_4, 0.6 g.; K_2HPO_4, 0.4 g.; $MgSO_4 \cdot 7H_2O$, 0.5 g.; $FeC_6H_5O_7 \cdot 5H_2O$, 10.0 mg. (6); $ZnSO_4 \cdot 7H_2O$, 4.4 mg.; $MnSO_4 \cdot 4H_2O$, 5.0 mg.; $CaCl_2$, 55.0 mg.; $CoCl_2 \cdot 6H_2O$, 1.0 mg.; and distilled water to 1 liter. Fifty ml. of medium was placed in each 250-ml. Erlenmeyer flask, sterilized at 121°C. for 20 minutes and inoculated with 0.5 ml. of a spore suspension that contained approximately 2 million spores per ml. After 7 days in the incubator, the mycelium was collected on tared filter paper, washed with 200 ml. of distilled water, and dried at 100°C. for 24 hours; and dry weight was determined.

Potato dextrose agar was used as the growth medium in the agar culture experiments. These cultures were inoculated by inverting a plug, cut with a No. 3 cork borer from an actively growing culture, in the center of the petri plate. After 5 days in the incubator, the mean diameter of each culture was determined by measuring the culture diameter at two locations at right angles to each other.

All treatment combinations were repeated twice. Four replications were included each time for both the liquid and agar cultures.

RESULTS

The optimum constant temperature for growth of all the isolates in liquid culture — except F5P2 — was 25°C. or lower; the optimum constant temperature for all isolates in agar culture was 25°C. or higher (fig. 1). Larger dry-weight differences were found among the isolates in liquid culture than in agar culture.

In liquid culture, a 6°C. fluctuation around a mean of 25°C. caused a reduction in growth of three isolates of *F. solani* and an increase of two isolates (fig. 2), but fluctuations of 12 and 18°C. caused a reduction in growth of all isolates. Fluctuation ranges of 6 and 12°C. around a mean of 25°C. had very little effect on growth of any of the isolates in agar culture, but an 18°C. fluctuation caused a slight reduction in growth of all the isolates.

Growth of only one isolate, F2P, was reduced with a 6°C.

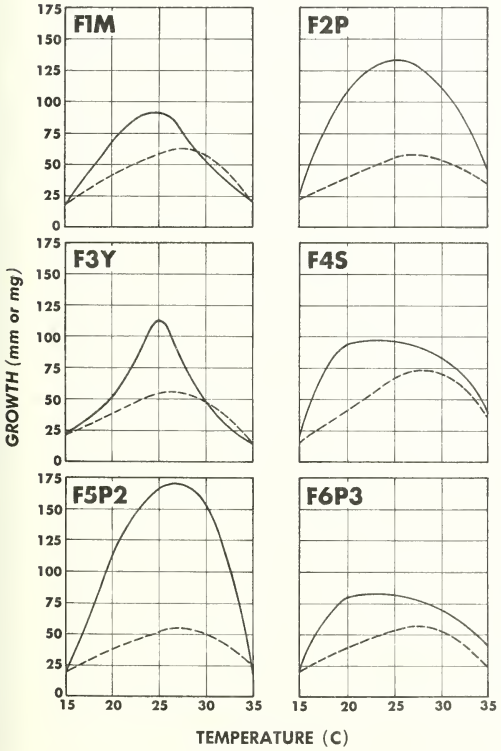

Figure 1. — Effect of constant temperature on growth of *F. solani* isolates in liquid culture (—) and agar culture (– –). Measurement of growth in liquid culture is in mg., and measurement of growth in agar culture is in mm.

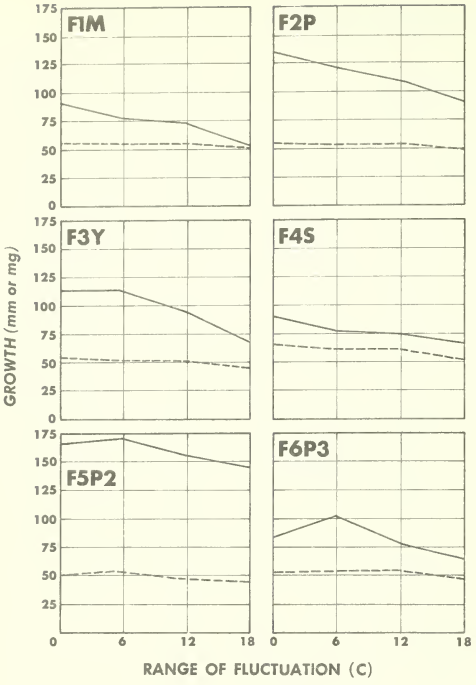

Figure 2.—Effect of fluctuating temperature around a mean of 25°C. on growth of isolates of *F. solani* in liquid culture (—) and agar culture (– –). Measurement of growth in liquid culture is in mg., and measurement of growth in agar culture is in mm.

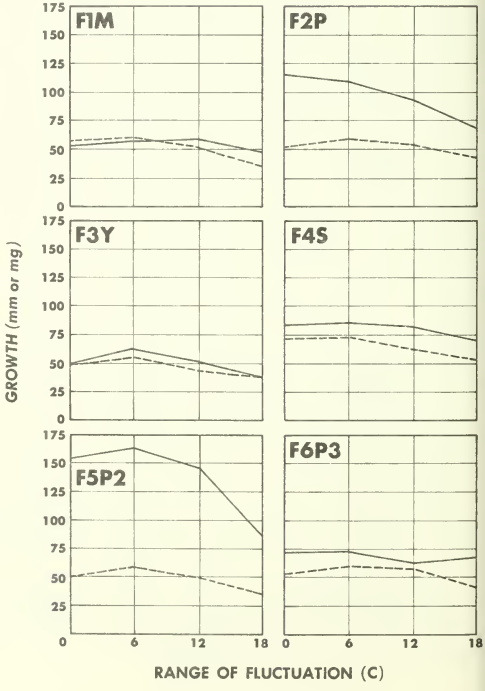

Figure 3.—Effect of fluctuating temperature around a mean of 30°C. on growth of isolates of *F. solani* in liquid culture (—) and agar culture (– –). Measurement of growth in liquid culture is in mg., and measurement of growth in agar culture is in mm.

fluctuation around a mean of 30°C. (fig. 3) in liquid culture, but no reduction was found in any of the isolates in agar culture. A 12°C. fluctuation caused a large reduction in growth of F2P in liquid culture and a small reduction for all isolates in agar culture — except F2P and F6P3 — compared to growth at 30°C. An 18°C. fluctuation caused a reduction in growth of all isolates in agar culture and of all isolates, except F6P3, in liquid culture.

DISCUSSION

To determine if fluctuating temperature itself affects growth of the fungus, growth under fluctuating temperature regimes was compared with growth under a constant temperature regime at the midpoint of the fluctuation range and with the shape of the constant temperature growth curve over the fluctuation range.

If fluctuating temperature does not affect growth, growth under the fluctuating temperature regime will be equal to growth under the constant temperature regime when the constant temperature growth curve over the range of fluctuation is linear; growth under the fluctuating temperature regime will be less than growth under the constant temperature regime when the constant temperature growth curve over the range of fluctuation curves downward; growth under the fluctuating temperature regime will be greater than growth under the constant temperature regime when the constant temperature growth curve over the range of fluctuation curves upward.

From an inspection of the constant temperature growth curves of *F. solani* in liquid culture around 25°C., growth under all the fluctuating temperature regimes with a midpoint of 25°C. should be less than growth at a constant temperature of 25°C. However, growth of three isolates either remained the same or increased with a 6°C. fluctuation range. From an examination of the constant temperature growth curve for liquid culture around 30°C., only two isolates, F1M and F3Y, should increase in growth in a fluctuating temperature regime. However, growth of all but one isolate, F2P, increased or remained the same with a small range of fluctuation.

In agar culture, growth in all the fluctuating temperature regimes with a midpoint of 25°C. was very close to growth in a 25°C. constant temperature regime. Growth in agar culture in fluctuating temperature regimes with a midpoint of 30°C. was less than growth in a 30°C. constant temperature regime only at the wide ranges of fluctuation. From an inspection of the constant temperature growth curves for agar cultures around 25 and 30°C., growth in all fluctuating temperature regimes would have been expected to be less than growth at the midpoint of the fluctuation range. This is especially true for the 18°C. fluctuation range.

These increases in growth of *F. solani* in fluctuating temperature regime that are not predicted from constant temperature growth suggest that temperature fluctuation itself affects the growth of some fungi. This conclusion is not in agreement with the conclusion reached by Burgess and Griffin (*1*) who proposed a model for predicting growth of fungi under fluctuating temperature regimes from constant temperature growth data, based on the assumption that temperature change itself does not affect the growth rate of fungi. These growth data were collected from agar cultures, but an analysis of our data suggests that growth, both in agar and liquid culture, may be affected by fluctuating temperatures.

The increase in growth of *F. solani* and decay fungi (*4*) with temperature fluctuations may be due to a carryover effect from more suitable to less suitable temperature or a direct effect of temperature on the organism. A positive carryover effect would occur if some temperature-sensitive system within the fungi would continue to function briefly at the high level obtained at a suitable temperature for a short period after the suitable temperature had passed. However, if this can occur, a negative carryover effect from less suitable to more suitable temperature may also occur. Burgess and Griffin (*1*) stated that detrimental effects of high temperature may have persisted and affected later growth at lower temperature, and that this may be the reason for the failure of their model at extreme temperatures.

A direct effect of temperature fluctuation on higher plants has

been reported. Kramer (5) and Hellmers (3) found that certain tree species made the best growth under the largest day-night differentials. Therefore, some fungi may also grow more if they are exposed to fluctuating temperatures as physiological processes within fungi each have a temperature optimum (2).

In this study we also compared growth in agar cultures and in liquid cultures. Two situations are evident: (1) the optimum temperature depends on the growth substrate, and (2) dry-weight measurements in liquid cultures give a larger range of differences than do diameter measurements in agar culture. Because of this larger range of differences, growth in liquid cultures is more sensitive than growth in agar cultures for measuring the effect of temperature treatments on growth of fungi. Also, in liquid culture all the growth is measured, whereas in agar culture only the horizontal spread is measured.

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■

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by Stanley M. Filip
and Elbert L. Little, Jr.

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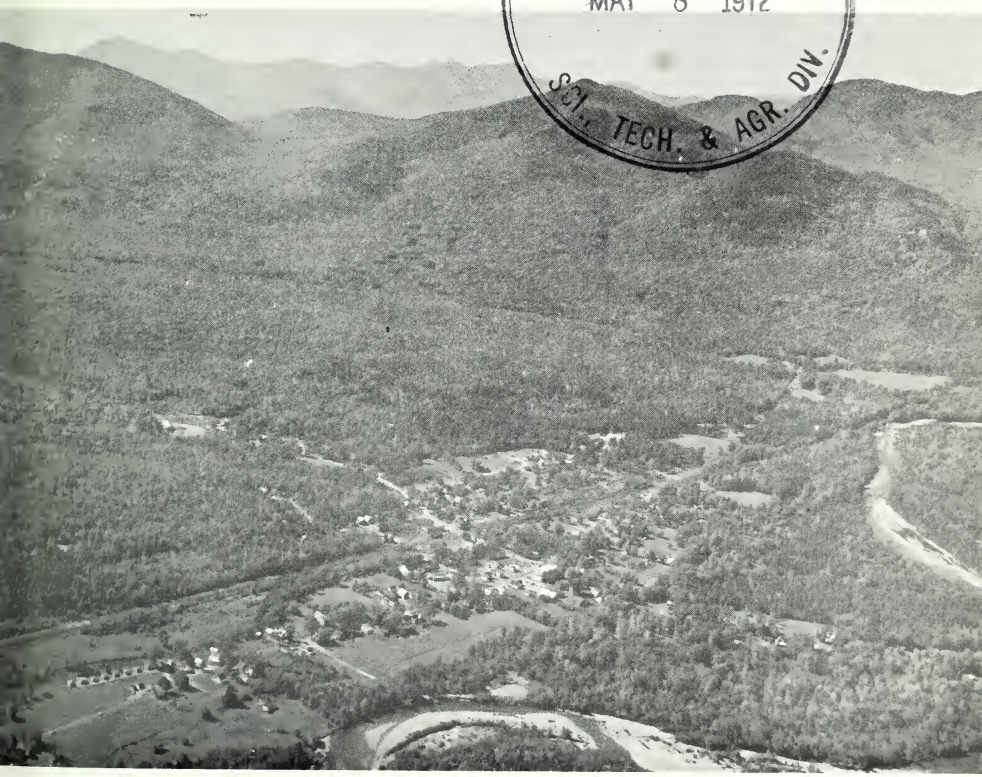

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COVER PHOTO: Aerial view of the Bartlett Experimental Forest. Bartlett Village and Saco River in the foreground.

TREES and SHRUBS of the BARTLETT EXPERIMENTAL FOREST Carroll County, New Hampshire

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THE BARTLETT FOREST

SIXTY-FIVE SPECIES of trees and shrubs have been identified as native on the Bartlett Experimental Forest. These species are listed in this paper to provide a record of the woody vegetation of the area.

The Bartlett Experimental Forest, part of the White Mountain National Forest, is adjacent to and south of the village of Bartlett, within the town of Bartlett, in the northwestern part of Carroll County in central New Hampshire (fig. 1). This 2,600-acre tract is located in the heart of the White Mountains, only 14 air-miles south of Mt. Washington, the highest peak in the Northeast, elevation 6,288 feet. Many forest conditions here are representative of 10 million acres of the northern hardwood forest ecosystem in New England.

The Bartlett Forest is one of the oldest experimental forests in the East. In 1928, when Congress authorized a comprehensive program of forest research, the Forest Service, U. S. Department of Agriculture, began establishing regional forest experiment stations and related research facilities throughout the United States. As part of this program, a segment of the White Mountain National Forest was set aside as the Bartlett Forest in 1931 for experimental purposes, with emphasis on basic and applied studies in ecology, silviculture, and management of northern hardwoods.

The Bartlett Forest has been used for this purpose ever since. At present the Forest is managed by the Northeastern Forest Experiment Station's research project on growth, composition, and culture of northern hardwoods, headquartered at Durham, New Hampshire *(NE. Forest Exp. Sta. 1969)*.

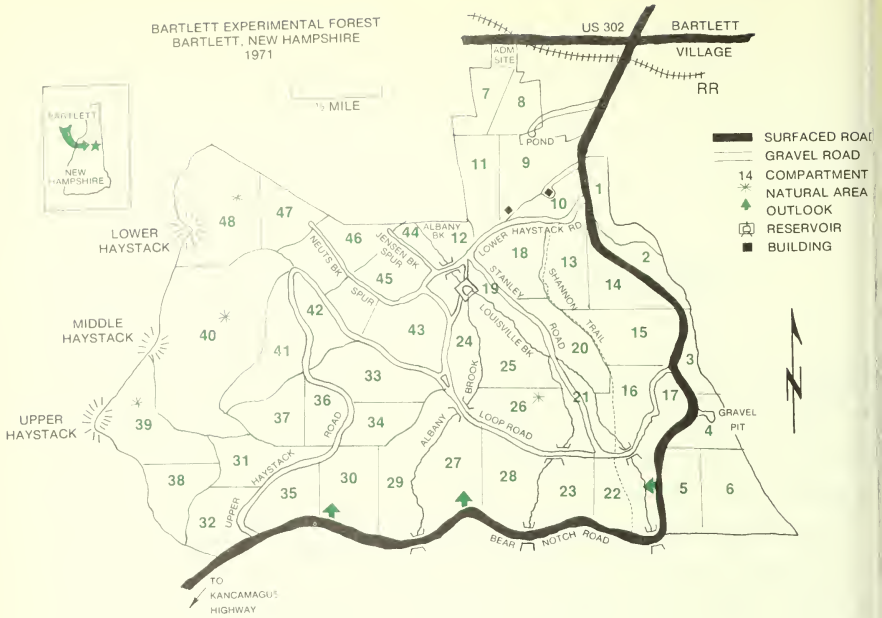

Figure 1.—Bartlett Experimental Forest, a part of the White Mountain National Forest, is located near the village of Bartlett, in central New Hampshire.

History

The earliest commercial logging on the Bartlett Forest took place about 1870. By 1900 the area had been logged several times. Only the best trees were taken in these operations. First the best spruce and white pine logs were taken. Later the best yellow birch and sugar maple were taken. Beech was seldom harvested, which increased the proportion of this species on the Forest.

During this early period, a logging railroad was built from the village of Bartlett up through the Forest. Many of the hardwood stands adjacent to this railroad were clearcut for fuel for the wood-burning locomotives. A few logging camps were established on the lower part of the Forest near Bartlett Village. The surrounding land was cleared and used for pasture, and some was cultivated.

Most of the desirable timber had been harvested by 1900. Then the logging ended, except for the harvesting of hemlock bark for tannin during World War I and some scattered cutting for fuelwood and paper birch millwood. After the railroad ceased operations, the cleared and pastured areas and the few cultivated areas reverted to forest.

Topography and Soils

The Bartlett Forest lies on the northern and eastern slopes of Bear Mountain (elevation 3,217 feet) and the Bartlett Haystack Mountains, recognized locally as the Lower, Middle, and Upper Haystacks. Elevations above sea level range from 680 feet at the lower end of the Forest to 2,995 feet at the summit of the Upper Haystack. The lower half of the Forest is gently sloping. The upper half is steep and rocky (fig. 2). Rock outcrops and ledges are common near the highest elevations.

The soils generally are sandy loams, derived through glacia-

Figure 2.—Gentle lower slopes and steep upper slopes characterize the Bartlett Experimental Forest.

tion from granites and schists. Many of the soils are well drained, but some moderately well drained and poorly drained soils are interspersed, especially on lower elevations.

Climate

The average annual precipitation of about 50 inches is distributed fairly evenly throughout the year. About one-third of the moisture comes in the form of snow. As much as 5 to 6 feet of snow accumulates on the ground by the latter part of the winter and remains until mid-spring.

Average monthly temperatures range from 15° to 20° F. in January to nearly 70° F. in July. Temperature extremes range from about 35° F. below zero to the upper 90's. The growing season—the time between the first and last killing frosts—is a little over 100 days. Central New Hampshire is in Plant Hardiness Zone 4, which has average annual minimum temperatures of —30° to —20° F. *(U. S. Nat. Arboretum 1965).*

Vegetation

Nearly all of the Forest is now covered by high forest. The only exceptions are those areas recently subjected to experimental cuttings or occupied by roads, trails, gravel pits, brooks, and one small boulder field. A small amount of open meadow is found adjacent to one lower corner of the Forest.

The primary forest cover type is the sugar maple-beech-yellow birch type (fig. 3), classified by the Society of American Foresters as type 25 *(S. A. F. 1945).* The upper elevations support thickets of spruce and fir. Softwoods such as hemlock, balsam fir, and spruce are commonly mixed with hardwoods, especially on cool steep slopes or on the poorly drained soils at lower elevations. Although white pine occurs mostly in stands at lower elevations, scattered specimens can be found over a large part of the Forest. Because of its northeasterly aspect, the Forest does not contain any extensive stands of oak. However, oak types are fairly common nearby on southerly and westerly slopes.

Figure 3.—From left to right: American beech, sugar maple, and yellow birch—the three characteristic tree species of the northern hardwood forest ecosystem in the Northeast.

NATURAL AREAS

Four compartments (26, 39, 40, and 48), in all about 500 acres, have been set aside as natural areas. These compartments, like the rest of the Forest, have been logged over in the past. However, no cutting has been done since 1900, and none is planned for the future. The sites, which vary from lowlands to upper slopes, will provide places for studying the development of the forest ecosystem under undisturbed conditions.

THE TREES AND SHRUBS

The list of trees and shrubs on the Bartlett Forest is based upon herbarium specimens collected by the authors in 1967, 1968, and 1969. Collections were made in the different forest types. Also, field trips were made on foot to the summit of Middle Haystack and to the saddle between Middle and Upper Haystacks.

The identifications were checked by Elbert L. Little, Jr. Scientific names of trees are those accepted in the U. S. Forest Service Check List *(Little 1953)*. Scientific names of shrubs follow Hodgdon and Steele *(1958)*.

Duplicate sets of about 115 specimens have been deposited in the Forest Service Herbarium now at Fort Collins, Colorado (formerly at Washington, D. C.), at the Bartlett Forest, and at the Herbarium of the University of New Hampshire, Durham, N. H. The Forest Service Herbarium also has 7 specimens collected from this by H. F. Morey in August-September 1934.

The native woody plants of the Bartlett Forest total 65 species in 43 genera and 21 plant families. However, 5 families together contain 36 species, more than one-half the total. Largest families are Rosaceae, with 6 genera and 11 species; Pinaceae and Capri foliaceae, each with 5 genera and 6 native species; Betulaceae, with 4 genera and 7 species; and Ericaceae, with 4 genera and 6 species. Thirteen families are represented by a single genus of woody plants, and 8 of these families by a single native woody species.

The largest genera of woody plants are *Acer, Betula,* and *Rubus,* with 4 species each, and *Salix* and *Prunus,* with 3 each. Only 4 varieties have been distinguished, and these are included in the species total. Two herbaceous species of woody genera are listed also, but are not counted in the totals. They are *Aralia racemosa* (spikenard) and *Cornus canadensis* (bunchberry).

Three introduced species add 2 genera and 1 family (Berberidaceae) to the totals above. These are *Pinus sylvestris* (Scotch pine), *Malus pumila* (apple), and *Berberis thunbergii* (Japanese barberry). All are rare on the Bartlett Forest. The first two are planted trees; the last is an introduced small shrub, possibly from seed brought in by birds.

These records will serve as a basis for future observations of introduced woody plants. Additional species now unknown here may be located or become established later.

Because this upland area has no permanent rivers or lakes and no peat bogs, woody plants of those wet sites are lacking. Also, this mountainous area in the White Mountains has a relatively colder climate than nearby areas along the Atlantic coast. Thus some southern species are absent here inland even though they extend farther northward near sea level. Also, the mountains are

not high enough for a timberline, so the dwarf shrubs of the subalpine and alpine zones are absent.

The recently published list of the trees and shrubs of the Penobscot Experimental Forest *(Safford et al. 1969)* provides a comparison. That area is located in Maine slightly farther north but near the coast at an altitude of 80-250 feet, and is bordered by a stream and a pond. Native woody plants of the Penobscot Forest total 98 species in 56 genera and 23 families. Thus the number of species is more than one and one-half times the total of 65 species found on the Bartlett Forest.

The relatively large number of plant families represented among the woody plant species of the Bartlett Forest and the small number of genera and species in a family may be of some significance. For example, the families average only 2 genera and 3 species of native woody species, and the genera have mostly 1 or 2 woody species.

Several species apparently are the northernmost or hardiest representatives of their genus or family in northeastern North America or in the northern hardwoods or eastern deciduous forests. For example, there is only 1 native species each of *Quercus, Ulmus, Crataegus,* and *Tilia.* Certain tree genera of the eastern United States are absent, not ranging so far north, at least in mountains. These include *Carya, Castanea, Celtis, Morus, Liriodendron, Magnolia, Sassafras, Liquidambar, Platanus, Robinia, Aesculus,* and *Nyssa.* No range extensions or unusual records were found at the Bartlett Forest. All the native woody plant species of the Forest have been cited previously from Carroll County by Foster *(1946),* Hodgdon and Steele *(1958),* Nehring and Leighton *(1967),* and Steele and Hodgdon *(1968).*

The woody plant species of the Bartlett Forest can be grouped conveniently into several classes according to size and growth form. These are large, medium, and small trees; large and small shrubs; and subshrubs. The 65 native species are:

Large Trees

(taller than 70 feet and 24 inches d.b.h. or larger; 8 species)

Pinus strobus
Tsuga canadensis
Acer rubrum
Acer saccharum
Betula alleghaniensis
Fagus grandifolia
Fraxinus americana
Quercus rubra

Medium Trees

(30 to 70 feet tall and 12 to 24 inches d.b.h.; 12 species)

Abies balsamea
Picea rubens
Pinus resinosa
Betula cordifolia
Betula papyrifera
Fraxinus nigra
Juglans cinerea
Populus grandidentata
Populus tremuloides
Prunus serotina
Tilia americana
Ulmus americana

Small Trees

(less than 30 feet tall and less than 12 inches d.b.h., commonly less than 6 inches d.b.h.; 13 species)

Acer pensylvanicum
Acer spicatum
*Alnus rugosa**
*Amelanchier laevis**
Betula populifolia
Cornus alternifolia
*Hamamelis virginiana**
Ostrya virginiana
Prunus pensylvanica
*Prunus virginiana**
*Rhus typhina**
*Salix discolor**
Sorbus americana

Large Shrubs

(taller than 5 feet; 10 species)

Cornus stolonifera
Corylus cornuta
Crataegus macrosperma
Ilex verticillata
Nemopanthus mucronata
Salix humilis
Salix rigida
Sambucus pubens
Viburnum alnifolium
Viburnum cassinoides

Small Shrubs

(shorter than 5 feet, often only 1 to 2 feet tall; 14 species)

Juniperus communis var. *depressa*
Taxus canadensis
Diervilla lonicera
Gaylussacia baccata
Kalmia angustifolia
Lonicera canadensis
Rhus radicans var. *rydbergii*
Ribes glandulosum
Rubus allegheniensis
Rubus canadensis
Rubus strigosus
Spiraea latifolia
Vaccinium angustifolium var. *laevifolium*
Vaccinium myrtilloides

*Often classified as a large shrub.

Subshrubs
(with creeping or trailing stems or with erect herbaceous stems slightly woody at base; 8 species)

Aralia hispida	*Gaultheria procumbens*
Aralia nudicaulis	*Linnaea borealis* var. *americana*
Chimaphila umbellata	*Mitchella repens*
Gaultheria hispidula	*Rubus pubescens*

These figures on growth forms show the effect of the colder northern climate on reduction of plant size. Of the 33 tree species, only 8 become large, the maximum size being about 90 feet in height and 30 inches d.b.h. Shrubs total 32 species: 10 large, 14 small, and 8 subshrubs. Thus there are relatively few species of large trees, many species of small shrubs, and a conspicuous element of subshrubs with creeping stems. Also, woody vines, with climbing or twining stems, though characteristic of warmer regions, are absent.

ANNOTATED LIST

PINACEAE: PINE FAMILY

Abies balsamea (L.) Mill. balsam fir

A medium-size tree, up to 14 inches d.b.h. Reaches best development on somewhat poorly drained softwood sites on lower slopes. Common as a small, sometimes stunted, tree in spruce-fir forests at elevations above about 2,500 feet.

Juniperus communis L.
var. *depressa* Pursh oldfield common juniper

A small spreading shrub, up to 4 feet tall. Found in old pastures and fields, it disappears from areas maintained in timberland. Not common. (Also placed in Cupressaceae, cypress family.)

Picea rubens Sarg. red spruce

Occurs in fair numbers as a medium-size tree on somewhat poorly drained softwood sites at lower elevations. Reaches largest size, up to 20 inches, in small groups, or as scattered trees, on northerly slopes in northern hardwood stands at

middle elevations. Occurs as a small tree in spruce-fir stands above about 2,500-foot elevation.

Pinus resinosa Ait. **red pine**

A medium-size tree, up to 24 inches d.b.h.; a scattered natural associate of white pine on sandy soils at lower elevations.

Pinus strobus L. **eastern white pine**

Reduced in numbers because of heavy cutting in the past; occurs mostly in small groups as a large tree, up to 30 inches d.b.h., in second-growth stands of softwoods or mixed softwood-hardwood stands at lower elevations.

Pinus sylvestris L. **Scotch pine**

Several planted trees of small size (6 to 8 inches d.b.h.) and low vigor are present on the northeasterly end of the Experimental Forest.

Tsuga canadensis (L.) Carr. **eastern hemlock**

A large tree that is abundant in somewhat poorly drained softwood sites at lower elevations, and a common associate in typical northern hardwood stands. Attains a diameter of 30 inches or more.

TAXACEAE: YEW FAMILY

Taxus canadensis Marsh. **Canada yew**

A small evergreen shrub, up to 3 feet tall. Common under both softwood and mixed hardwood-softwood stands on both lower and upper slopes of the Experimental Forest.

ACERACEAE: MAPLE FAMILY

Acer pensylvanicum L. **striped maple**

A small tree, up to 5 inches d.b.h. Bark on young trees is green-and-white striped. Fairly abundant, growing under older northern hardwood stands on middle and upper slopes.

Acer rubrum L. red maple
An abundant, very widely distributed tree of large size, up to more than 30 inches d.b.h. Commonly occurs as stump sprouts in cutover areas.

Acer saccharum Marsh. sugar maple
Largest and most valuable of the maples. Attains a breast-height diameter up to 30 inches. An abundant and characteristic component of northern hardwood stands.

Acer spicatum Lam. mountain maple
A small tree, up to 3 inches d.b.h., fairly common under older northern hardwood stands, especially on rocky areas in the middle to higher elevations.

ANACARDIACEAE: CASHEW FAMILY

Rhus radicans L. var. *rydbergii* (Small) Rehd. poison-ivy
A small shrub, rare on the Experimental Forest; confined mostly to a moist area along the road in compartment 43.

Rhus typhina L. staghorn sumac
A small tree, up to 20 feet tall. Common in abandoned meadows or pastures adjacent to the Experimental Forest.

AQUIFOLIACEAE: HOLLY FAMILY

Ilex verticillata (L.) Gray winterberry
A large shrub, up to 10 feet tall, found in fair numbers under open second-growth northern hardwoods, usually on poorly drained soils.

Nemopanthus mucronata (L.) Trel. mountain-holly
A large shrub, up to 6 feet tall, found in fair numbers in second-growth northern hardwood stands at lower elevations.

ARALIACEAE: GINSENG FAMILY

Aralia hispida Vent. **bristly sarsaparilla**

A subshrub with stem slightly woody at base. Common in recent openings and dry rocky areas.

Aralia nudicaulis L. **wild sarsaparilla**

A subshrub, almost stemless, with leaf and flower stalk, up to 1½ feet tall, commonly found under second-growth hardwoods and mixed softwood-hardwood stands at the lower elevations.

Aralia racemosa L. **spikenard**

A stout perennial herb up to 3 feet tall. Common in rich, moist areas.

BERBERIDACEAE: BARBERRY FAMILY

Berberis thunbergii DC. **Japanese barberry**

A small shrub, rare on the Experimental Forest, confined mostly to a red maple swamp stand in Compartment 7. Introduced into the United States from Japan as an ornamental, escaped from cultivation and perhaps spread by birds.

BETULACEAE: BIRCH FAMILY

Alnus rugosa (Du Roi) Spreng. **speckled alder**

A small tree or large shrub, not over 15 feet tall, that grows in clumps or thickets along streams or other wet places, usually in the open or partial shade.

Betula alleghaniensis Britton **yellow birch**

One of the characteristic and most valuable trees in the northern hardwood forest ecosystem. The largest of all birches, up to 30 d.b.h., it is found in both typical hardwood as well as mixed softwood-hardwood stands. Occurs as a small tree at elevations above about 2,000 or 2,500 feet. (*B. lutea* Michx. f.)

Betula cordifolia Regel **mountain paper birch**

A medium-size tree resembling *B. papyrifera* in habit, but slower growing and more prevalent on middle to high slopes,

and usually on cool sites. (*B. papyrifera* Marsh. var. *cordifolia* (Regel) Fern.) Also called white birch and canoe birch.

Betula papyrifera Marsh. **paper birch**
A medium-size tree, up to 18 inches d.b.h., characterized by white bark, sometimes pinkish, on trees larger than 2 to 3 inches d.b.h. Found in hardwood and mixed hardwood-softwood stands, mostly on low to middle slopes. Valued highly for millwood and sometimes veneer logs. A valuable tree aesthetically. Also called white birch and canoe birch.

Betula populifolia Marsh. **gray birch**
A small short-lived pioneer tree, up to 6 inches d.b.h., that occurs in old fields, old burns, or as a scattered tree following clearcuttings in northern hardwood stands.

Corylus cornuta Marsh. **beaked hazelnut**
A large shrub in forest openings, uncommon on the Experimental Forest.

Ostrya virginiana (Mill.) K. Koch **eastern hophornbeam**
A small tree, up to 10 inches d.b.h., widely distributed—but not abundant—in second-growth northern hardwood stands.

CAPRIFOLIACEAE: HONEYSUCKLE FAMILY

Diervilla lonicera Mill. **bush-honeysuckle**
A small shrub, up to 4 feet tall, found in rocky areas and open woods. Distinguished from fly honeysuckle by the slightly serrate and larger leaves.

Linnaea borealis L.
var. *americana* (Forbes) Rehd. **twin-flower**
A subshrub with creeping stems and small rounded evergreen leaves. Occurs in cool moist areas at low to middle elevations.

Lonicera canadensis Marsh. **fly honeysuckle**
A small shrub with straggling habit, fairly common in rocky areas, in open woods. Leaves are entire, in contrast to the bush-honeysuckle.

Sambucus pubens (Michx.) Koehne **red-berried elder**

A large shrub, up to 10 feet tall. Common but not abundant along roads and in other open places. (*S. racemosa* L. var. *pubens* (Michx.) Koehne).

Viburnum alnifolium Marsh. **hobblebush**

A common and abundant large shrub, up to 10 feet tall, characterized by its bright red berries. Grows in thickets under closed or partially opened hardwood and softwood stands. Also called witch-hobble.

Viburnum cassinoides L. **withe-rod**

A large shrub, up to 6 feet tall, that is fairly common in swamps and poorly drained areas at lower elevations. Also called wild-raisin.

CORNACEAE: DOGWOOD FAMILY

Cornus alternifolia L. f. **alternate-leaf dogwood**

A small tree, up to 20 feet tall, found in small numbers in moist areas, usually in somewhat open hardwood stands.

Cornus canadensis L. **bunchberry**

A small perennial herb, less than 8 inches tall, characterized by a whorl of dogwood-like leaves. Common under cool moist softwood and mixed hardwood-softwood stands throughout a wide range in elevation.

Cornus stolonifera Michx. **red-osier dogwood**

A large shrub, usually not over 6 feet tall, that forms small thickets in meadows or open woodlands. Uncommon on the Experimental Forest.

ERICACEAE: HEATH FAMILY

Gaultheria hispidula (L.) Bigel. **creeping snowberry**

A subshrub with wiry creeping stems and minute evergreen leaves. Occurs mostly in softwood stands at low to middle elevations (*Chiogenes hispidula* (L.) T. & G.)

Gaultheria procumbens L. wintergreen

A small creeping evergreen subshrub, occurring in patches under either dense or partially open softwood or mixed softwood-hardwood stands.

Gaylussacia baccata (Wang.) K. Koch black huckleberry

A small shrub up to 2 feet tall, found on rocky sites at high elevations.

Kalmia angustifolia L. lambkill

An evergreen shrub, usually less than 3 feet tall, that occurs in small pockets of moist soil under partially open second-growth hardwood or mixed softwood-hardwood stands.

Vaccinium angustifolium Ait. var. *laevifolium* House lowbush blueberry

A small shrub up to 1 foot tall, found at low and middle elevations in well-drained and often rocky sites.

Vaccinium myrtilloides Michx. blueberry

A small shrub up to 2 feet tall. Common in open and partially timbered areas, under a wide variety of conditions ranging from moist soils at lower elevations to rocky sites at higher elevations.

FAGACEAE: BEECH FAMILY

Fagus grandifolia Ehrh. American beech

A large tree, up to 30 inches d.b.h., and one of the characteristic and most abundant in the northern hardwood forest ecosystem. Widely distributed throughout a range of soils, elevations, and timber types.

Quercus rubra L. northern red oak

A widely scattered tree on the Forest, except on one small area having a southerly aspect. Here it is more abundant. Nearly pure stands occur adjacent to the Experimental Forest on southerly and westerly slopes. Occasional trees are large, up to 80 feet tall and 28 inches d.b.h., and well formed (*Q. borealis* Michx. f.)

HAMAMELIDACEAE: WITCH-HAZEL FAMILY

Hamamelis virginiana L. **witch-hazel**

A small tree or large shrub, up to 15 feet tall, reasonably common in somewhat open second-growth hardwood stands at lower elevations.

JUGLANDACEAE: WALNUT FAMILY

Juglans cinerea L. **butternut**

Represented by one observed tree, about 10 inches d.b.h., and a few seedlings, near a logging road in Compartment 1. Not common in this area, especially on the north-facing aspects. Possibly introduced.

OLEACEAE: OLIVE FAMILY

Fraxinus americana L. **white ash**

A large and well-formed tree, up to 26 inches d.b.h., found on moist rich sites in northern hardwood stands. A common though not abundant tree of appreciable commercial importance.

Fraxinus nigra Marsh. **black ash**

A medium-size tree, up to 14 inches d.b.h., found in a few areas at low elevations on poorly drained soils.

PYROLACEAE: PYROLA FAMILY

Chimaphila umbellata (L.) Bart. **common pipsissewa**

A subshrub with short stem, a few inches high, and evergreen leaves. Found mostly in dry areas, especially in sandy soil. Also called prince's pine.

ROSACEAE: ROSE FAMILY

Amelanchier laevis Wieg. **Allegheny serviceberry**

A small tree or large shrub, up to 6 inches d.b.h., widely scattered throughout hardwood stands on the Experimental Forest. Also called shadbush.

Crataegus macrosperma Ashe (?) large-seed hawthorn

A large shrub found in openings and dry rocky soil. Rare on the Experimental Forest.

Malus pumila Mill. apple

A few trees planted in, or escaped to, openings at the edge of the Experimental Forest.

Prunus pensylvanica L. f. pin cherry

A small short-lived pioneer tree, up to 8 inches d.b.h. Rare in undisturbed older woods, but occurs in abundance, sometimes in thickets, following old burns or clearcutting of hardwood stands. Extends to higher elevations in the spruce-fir forest. Also called fire cherry.

Prunus serotina Ehrh. black cherry

Occurs in small numbers, especially on moist sites at lower elevations, as a medium-size tree up to 14 inches d.b.h. and 50 feet tall.

Prunus virginiana L. common chokecherry

A small tree or large shrub. Occurs in openings and edges of clearings at lower elevations. Uncommon on the Experimental Forest.

Rubus allegheniensis Porter common blackberry

A small shrub up to 4 feet tall. Invades abandoned fields, large clearcut areas, abandoned logging camps, etc., where it remains abundant for several years, eventually giving way to other shrubs and tree species.

Rubus canadensis L. thornless blackberry

A small shrub similar in habit to *R. allegheniensis,* but having nearly thornless canes.

Rubus pubescens Raf. dwarf red blackberry

A subshrub with stems mostly creeping. Occurs on abandoned fields and clearcut areas.

Rubus strigosus Michx. red raspberry

A small shrub, easily recognized by the whitish lower leaflet surfaces. Abundant for a few years on abandoned fields and clearcuttings. (*R. idaeus* L. var *strigosus* (Michx.) Maxim.)

Sorbus americana Marsh. **American mountain-ash**

A small tree, up to 5 inches d.b.h., usually found in small numbers on rocky slopes at higher elevations. (*Pyrus americana* (Marsh.) DC.)

Spiraea latifolia (Ait.) Borkh. **meadowsweet**

A small straight-stemmed shrub up to 3 feet tall. Common in meadows or abandoned pastures adjacent to the Experimental Forest.

RUBIACEAE: MADDER FAMILY

Mitchella repens L. **partridge-berry**

A subshrub with creeping perennial stems. Common under softwood and mixed hardwood-softwood stands at lower elevations.

SALICACEAE: WILLOW FAMILY

Populus grandidentata Michx. **bigtooth aspen**

A well-formed medium-size tree, up to 24 inches d.b.h., found as a scattered tree in second-growth hardwood stands that have originated after clearcutting or land clearing. Locally called popple.

Populus tremuloides Michx. **quaking aspen**

A medium-size tree, up to 14 inches d.b.h., sometimes poorly formed and cankered, found in groups in second-growth hardwoods originating after clearcutting or clearing. Locally called popple.

Salix discolor Mühl. **pussy willow**

A small tree or large shrub, up to 15 feet tall, found in open woodland along streams or even in dry areas.

Salix humilis Marsh. **upland pussy willow**

A large shrub found in open woodlands and dry areas.

Salix rigida Mühl. **heartleaf willow**

A large shrub, up to 6 feet tall; occurs in clumps in wet areas and along streams. Distinguished by the slightly heart-shaped leaf base. (*S. cordata* Mühl.)

SAXIFRAGACEAE: SAXIFRAGE FAMILY

Ribes glandulosum Grauer **skunk currant**

A small shrub, up to 2 feet tall among boulders at high elevations. (*R. prostratum* Gray.)

TILIACEAE: LINDEN FAMILY

Tilia americana L. **American basswood**

A medium-size tree, up to 14 inches d.b.h. Sparsely scattered throughout second-growth northern hardwood forests in moist areas at the lower elevations.

ULMACEAE: ELM FAMILY

Ulmus americana L. **American elm**

Occurs in small numbers in second-growth hardwood stands, usually as a medium-size tree, up to 14 inches d.b.h.

■

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Machine Driving of Wooden and Steel HIGHWAY GUARDRAIL POSTS under Adverse Conditions

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by Charles J. Gatchell
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 17 MAY 1971.

THE INSTALLATION of both wooden and steel highway guardrail posts by machine driving is an accepted procedure. owever, there has been no information about the damage that ight be done to the below-ground parts of these posts in driv- g. In talking with highway engineers in several states, we arned that a basic assumption is generally used: if the guard- il posts are undamaged above the groundline, we assume that ere is no damage below the groundline.

The potential for damage is often present. For primary and terstate construction in West Virginia, only the top 27 inches the roadbed always receives preparatory treatment. The top inches is aggregate, which will cause no damage to either ooden or steel posts. Below the top layer is a 12-inch-thick bgrade, which is supposed to contain rocks no larger than 3 ches. There is no guarantee that larger rocks will not be used. he whole subgrade may be made up of 3-inch rocks, and there no limit on rock size below the subgrade. Adverse driving nditions may damage both standard 6B8.5 steel posts that are iven to a depth of 33 inches and wooden posts that are driven a depth of 36 inches.

In an exploratory study, we drove 32 wooden posts and 26 eel posts into a rock-filled base that was topped with limestone avel and shale. We found that, though both post materials erform well, wood is superior to steel in resisting damage below ie groundline.

The Study

Only posts suitable for the "strong" post guardrail systems—W-beam guardrail and median barrier systems, for example—were driven. Posts were purchased on the open market from companies that supply contractors in West Virginia. The steel posts were type 6B8.5, 6-inch web, 4-inch flange, 5 feet 9 inches long, and weighed 8.5 pounds per lineal foot. The wooden posts were 7-inch diameter, 6-foot long southern pine that had been pressure-treated with a water-borne salt preservative.

All posts were driven in a 65-year-old one-lane gravel road. Originally constructed for a large lumber company, the road had received continual though limited use as a part of the West Virginia secondary road system.

The road, constructed across a narrow flood plain, provided

Figure 1.—Wooden and steel guardrail posts were driven into an old roadbed. A trench was excavated so the posts could be examined in place.

three driving sites. Site I began on natural ground and ended with a sandstone rock fill at the edge of what had once been the stream channel. Site II was a built-up section between the old and present stream channels. Site III began on the other side of the present channel and ended in natural ground.

The general plan was to drive all posts on 3-foot centers to a depth of about 4 feet, backhoe a 5-foot deep trench along the sides of the posts, and examine the posts in place (fig. 1). The driving hammer was always raised to its maximum height before being released.

Two commercial post drivers with different hammer weights were used. On site I, we used a machine supplied by Murphy Industries of Sherman, Texas. This machine had a 950-pound hammer with an initial free-fall height of 8 feet to the top of a 6-foot post. On sites II and III, we used a driver supplied by Sterling Products, Inc., of Kingston, Pennsylvania. This machine came equipped with hammers weighing 800 and 1,200 pounds. Each hammer had an initial free-fall height of 8 feet to the top of a 6-foot post.

NOTE. Rate of installation was not a subject of this study. Wooden posts can easily absorb much higher impacts than those used in this study. Rate of installation is a function of such factors as hammer weight, method of hammer delivery (automatic or manual stroke operation), ease of post loading, post plumbing, and machine disengagement from a driven post. As shown in an earlier report, driving time is usually a small part of post installation time *(Gatchell 1967)*.

The evaluation of post damage was subjective, based upon comments from highway engineers. The basic categories used were: none, light, moderate, and severe. *None* was used when damage extended no more than 8 inches from the base and, for wooden posts, was no more than 1 inch deep. *Light* damage was more extensive but, in our judgment, would not impair the performance of the post as guardrail support. *Moderate* damage,

which might cause rejection, included extensively bent flanges on the steel posts or long splits or gouges about an inch deep in the wooden posts. *Severe* damage, which would surely cause rejection of the posts, included extensive stripping of the flanges or curling or twisting of the web on the steel posts and extensive and deep splits in the wooden posts.

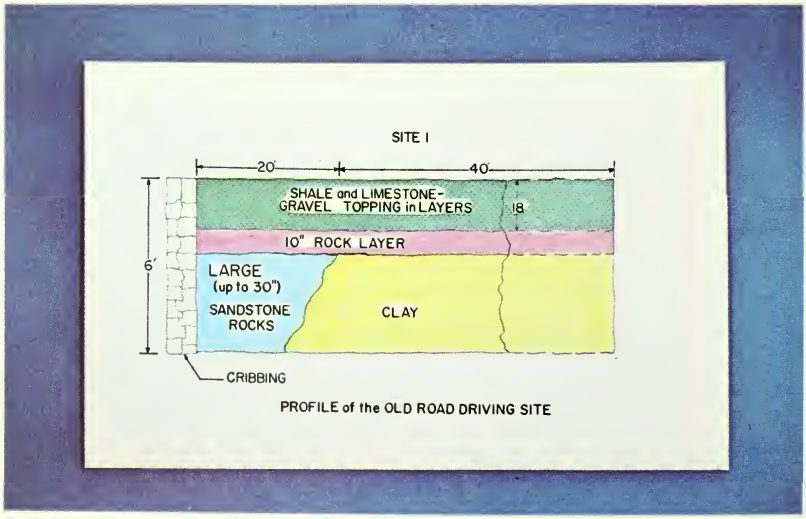
SITE I

Description

On site I (fig. 2) all posts were driven with a 950-pound hammer. Three wooden posts were driven into the rock base on one side of the road, and 10 steel and 7 wooden posts were driven on the other side. This arrangement of posts was made to allow easy access for the backhoe.

After digging the trench, we found that all of site I was topped with 15 to 18 inches of dry and highly compacted limestone gravel and shale in layers. We assumed that these layers were laid down over a long period of time as a part of road maintenance. A 10-inch-thick layer of small rocks had been placed between the clay base and the limestone and shale

Figure 2.—Profile of site I.



topping. This layer was not distinctly visible over the rock base. Extensive profile work in the clay base was not possible because the trench caved in shortly after being dug.

The three wooden posts and the first four steel posts had been driven into the sandstone rock base. Steel posts 5 and 6 were in a transition zone between the rock fill and the old stream bank. The other four steel posts and seven wooden posts were driven into the clay base.

Results

The seven wooden posts and the four steel posts driven into the clay base were undamaged, though a slight bending of the steel flanges was observed (table 1). This slight bending probably occurred in the 10-inch layer of rock between the clay base and the limestone-shale topping.

Table 1.—*SITE I: summary of post driving*

Post No.	Blows required, 4-foot depth	Type of base	Damage to post
	No.		
		STEEL POSTS	
1	12	Rock	Light
2	12	Rock	Severe
3	12	Rock	Light
4	19	Rock	Severe
5	11	Transition	None
6	15	Transition	Light
7	12	Clay	None
8	12	Clay	None
9	12	Clay	None
10	13	Clay	None
		WOODEN POSTS	
1	28	Rock	Very light
2	22	Rock	Very light
3	25	Rock	None
4	27	Clay	None
5	22	Clay	None
6	20	Clay	None
7	27	Clay	None
8	25	Clay	None
9	23	Clay	None
10	24	Clay	None

Figure 3.—The four steel posts and three wooden posts driven into the rock base of site I. The number of blows per post with the 950-pound hammer were (from left to right): steel post 1—12 blows; wooden post 1—28 blows; steel post 2—12 blows; wooden post 2—22 blows; steel post 3—12 blows; wooden post 3—25 blows; steel post 4—19 blows.

The condition of the three wooden posts and four steel posts driven into the rock base is shown in figure 3. Wooden post 3 was undamaged, and damage to the other two wooden posts would not impair their performance. These results are consistent with our earlier driving experience, using a 1,400 pound hammer. As a general rule, when a wooden post hits an obstruction, it either stops or moves the obstruction.

The four steel posts driven into the rock base suffered light to severe damage. Steel posts 1 and 3 had only minor damage to the flanges and would probably perform adequately. Steel posts 2 and 4 would be unacceptable for guardrail support. The flanges of steel post 2 were stripped from the web. Steel post 4, which took 19 blows to get to grade, suffered separation and curling

of the flanges and curling of the web. None of the wooden or steel posts was damaged above the groundline.

Steel posts 5 and 6, driven into the transition zone between the rock and clay bases, suffered minor damage to the flanges.

A significant observation is that the type of base did not affect the total number of blows (except for steel post 4, which suffered severe curling of the web). Further, there was little variation in the number of blows for each type of post. In the rock base, the three wooden posts averaged 25 blows per post, with a range of 22 to 28 blows. In the clay base, 7 wooden posts averaged 24 blows per post, with a range of 20 to 27 blows. Six steel posts required 12 blows per post for installation in the rock and clay bases. About three-fourths of the blows for each type of post were required to penetrate the dry compact top layers.

SITE II

Description

On site II (figs. 4 and 5) we drove lines of wooden and steel posts about 10 feet apart. Twelve wooden posts and 5 steel posts were driven with a 1,200-pound hammer. Five wooden posts and 11 steel posts were driven with an 800-pound hammer. Two of the 5 wooden posts were driven at the end of the steel post line. The use of the heavy hammer with wood and the light hammer with steel reflects currently recommended commercial practice.

At the time of driving (late October), which was preceded by an extended rainy period, the site was rather wet. The temperature was cool, and the relative humidity was high.

After backhoeing out the trench, we found site II to be much more variable than expected. The depths of the limestone-shale topping and the sandstone rock base along and between lines varied greatly. The severity of the conditions for the wooden posts was greater than those for steel. The rock base under the line of wooden posts was up to 9 inches deeper than that under the opposing position in the line of steel posts.

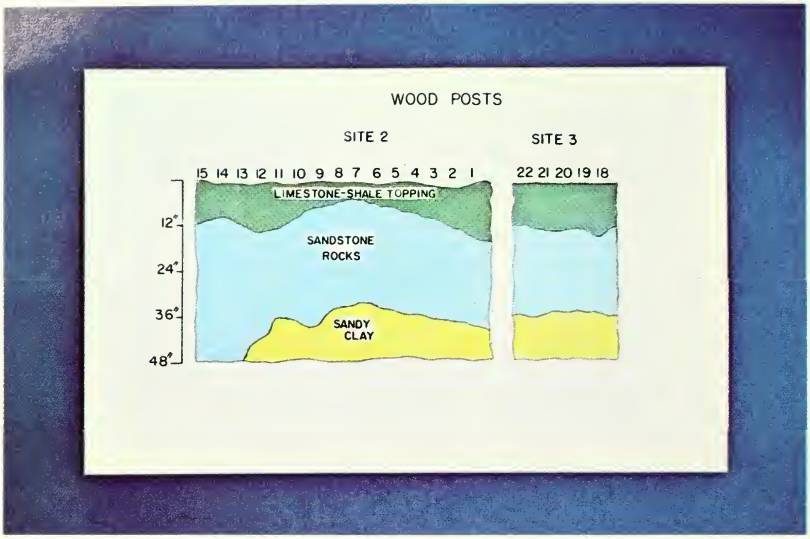


Figure 4.—Profile of sites II and III where wooden posts were driven. Numbers correspond to wooden posts as listed in tables 2 and 3.

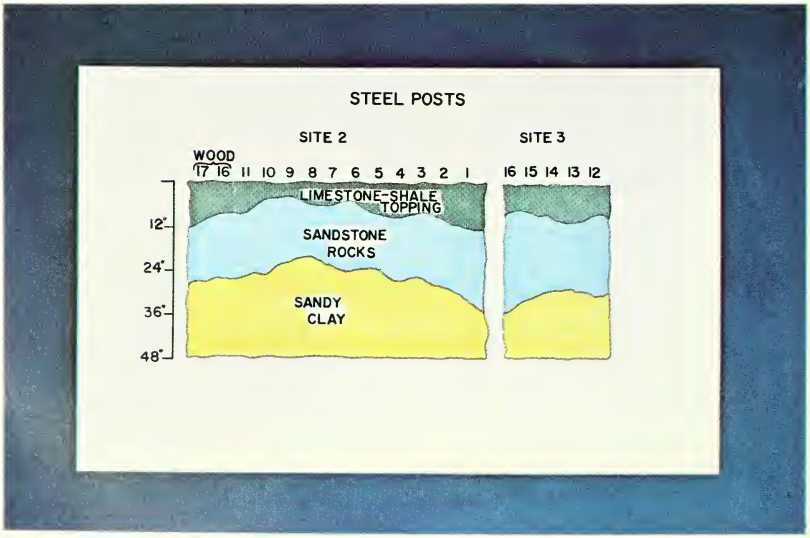


Figure 5.—Profile of sites II and III where steel posts were driven. Numbers refer to posts as listed in tables 2 and 3.

Results

Except for wooden posts 14 and 15, all posts penetrated the rock fill and ended in a clay base (table 2). Variations in the depth of the rock layer made comparisons difficult between the 800- and 1,200-pound hammer weights and between the wooden and steel posts.

We observed little damage or difference in the severity of damage to steel posts driven with the 800- and 1,200-pound

Table 2.—*SITE II: summary of post driving*

Post No.	Depth of topping	Depth of rock layers	Hammer weight	Blows required	Damage to post
	Inches	*Inches*	*Lbs.*	*No.*	
		STEEL POSTS			
1	16	20	1200	9	None
2	14	18	1200	10	Light
3	13	18	1200	17	Moderate
4	12	16	1200	11	Light
5	17	14	1200	10	None
6	3	22	800	21	Moderate
7	4	22	800	14	None
8	5	21	800	10	None
9	3	14	800	11	Light
10	3	21	800	12	Light
11	10	24	800	14	Moderate
		WOODEN POSTS			
1	20	24	1200	18	Light[1]
2	16	24	1200	24	Light[1]
3	14	24	1200	30	None[1]
4	10	24	1200	29	None
5	10	23	1200	27	None[1]
6	8	24	1200	25	Moderate[1]
7	8	23	1200	18	None[1]
8	6	22	1200	16	None
9	8	23	1200	23	None[1]
10	8	22	1200	28	Severe
11	14	24	1200	19	None
13	18	20	800	41	None
14	9	40+	800	53	Light[1]
15	18	40+	800	72	None[1]
[2]16	8	17	800	26	None[1]
[2]17	16	14	800	22	Light[1]

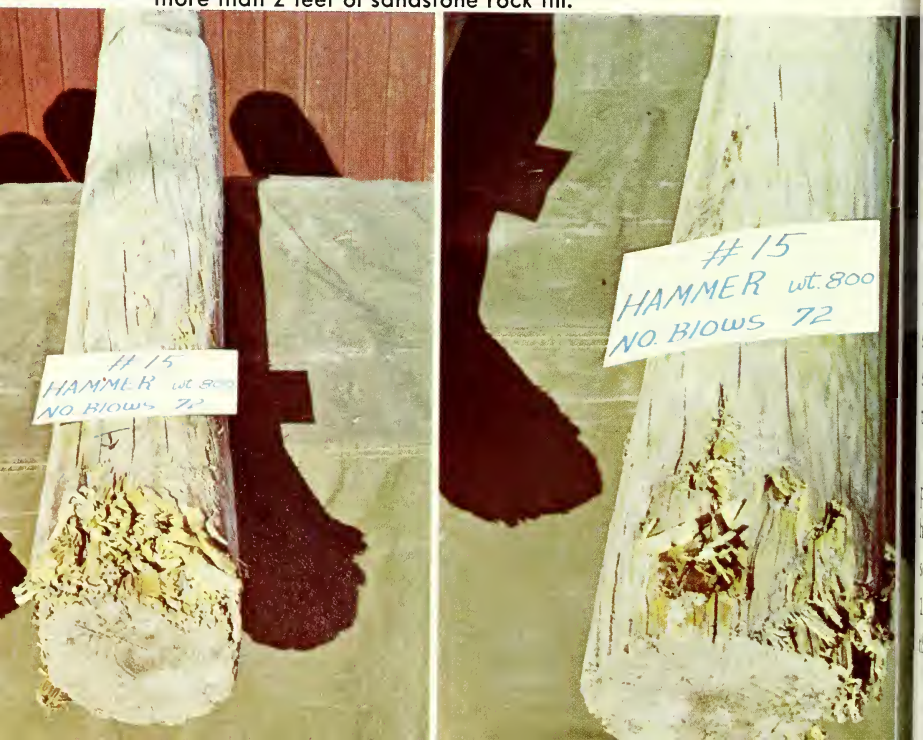
[1]Knots within 3 to 12 inches of bottom of post prevented or minimized damage.
[2]Driven at end of steel post line after steel post 11.

hammers. However, those driven with the 1,200-pound hammer penetrated about 5 inches less rock fill. We saw repeated examples of sandstone rocks that were cleanly broken by the posts. Damage was limited mostly to bending of flanges.

Steel posts 3, 6, and 11 might not have been suitable for guardrail support because of extensive flange damage. The other 8 posts should have been acceptable.

Of the 15 wooden posts driven on site II, posts 6 and 10 were significantly damaged. Damage was in the form of splits resulting from wedge-shaped rocks that had been driven into the base of the posts. We believe that wooden post 6 would have been serviceable because the damage was in that portion of the post that was completely treated with preservative. Post

Figure 6.—Two views of wooden post 15. Knots located within 4 inches of the base minimized the severity of damage that could have resulted from driving through more than 2 feet of sandstone rock fill.



10 had splits along its sides that may have penetrated to untreated wood in the center, and therefore this post was considered to be severely damaged.

The presence of knots within 3 to 12 inches of the base of a post is recommended to minimize the potential for splitting. Splits stop at the knots. Furthermore, on either side of the knot, the grain is not straight but is curved around the knots. This curving of the grain also tends to terminate splits. For example, wooden post 15 (fig. 6) required 72 blows with an 800-pound hammer to be driven into more than 2 feet of sandstone rock fill. Because knots were located about 4 inches from the base, damage to the post was superficial. The value of knots in reducing the severity of damage was observed on 11 of the 17 wooden posts driven on site II.

SITE III

Description

On site III (figs. 4 and 5), we drove a line of five wooden posts with the 1,200-pound hammer and a line of five steel posts with the 800-pound hammer. This site provided the greatest resistance to driving. As on site II, the wooden posts were driven under more severe conditions than were the steel posts; the rock base for the wooden posts was up to 10 inches deeper than that for the steel posts.

Results

Although site III offered the greatest resistance to driving (average of 30 blows per wooden posts), four wooden posts driven with the 1,200-pound hammer were undamaged, and one suffered only very light damage. The rocks in site III were smaller, rounder, and more tightly fitted than those in the other two sites (table 3).

Even though there was up to 10 inches less rock on the steel post side, three of the five steel posts driven with the 800-pound hammer were damaged. The damage ranged from light to severe. Post 15 had severe twisting of the web and flanges. Post 16 had curling of the web and separation of the flanges from the web.

Table 3.—*SITE III: summary of post driving*

Post No.	Depth of topping	Depth of rock layers	Hammer weight	Blows required	Damage to post
	Inches	*Inches*	*Lbs.*	*No.*	
			STEEL POSTS		
12	10	20	800	15	None
13	10	20	800	13	None
14	13	15	800	18	Light
15	13	18	800	16	Severe
16	10	23	800	16	Moderate
			WOODEN POSTS		
18	12	23	1200	33	None
19	14	23	1200	29	None[1]
20	13	25	1200	40	Light
21	13	26	1200	25	None
22	13	26	1200	23	None

[1]Knots minimized damage.

CONE FORMATION AT THE BASE OF BLUNT WOODEN POSTS

During machine driving, a flat-bottomed wooden post tends to form a cone of compressed material on its base (fig. 7). Cones were clearly visible in site II. The centers of the cones were made of limestone and shale with concentric conical layers of other materials on the outside (fig. 8). These cones were often present after the post was driven through 2 feet of sandstone rock fill. A sleeve of material from the top layers was often clearly visible around these posts. This sleeve was thickest near the groundline and tapered in toward the bottom of the post.

There are two major benefits to these cones. One is the reduction in resistance that would normally be associated with a cross-section 7 or more inches in diameter. The effect is similar to driving a pointed post.

The second major benefit is the protection the cone provides to the base of the post. The top layers generally will be composed of small pieces (1 inch or less) of topping, which do not cause damage. If a post with a cone beneath is driven onto a

Figure 7.—Cones of compressed top-layer material form at the base of flat-bottomed wooden posts. These cones reduce the resistance of the post to driving and help protect the bottoms of the post from damage.

Figure 8.—Section of cone formed at the base of wooden post 16. Center of the cone is made up of limestone and shale from the top 8 inches of the site profile. In the outer inch of the cone, concentric layers of other materials can be seen.

large rock, the cone must squeeze from between the post and rock before the rock can damage the post. However, each blow tends to move the rock. We believe that the protection provided by the cone is one major reason for the excellent performance of wooden posts under adverse conditions.

The Dynamic Interactions of Machine Driving

On site I, about three-fourths of the total number of blows were required to penetrate the top 15 to 18 inches of dry compact limestone gravel and shale. The total number of blows for each type of post was independent of the site base (sandstone rock fill or clay). On site II, cones of compressed top-layer material were found on the bases of wooden posts even after the posts had been driven through 2 feet of sandstone rock fill. On site III, which provided the greatest resistance to driving, wooden posts were undamaged. The base of site III was made up of smaller, rounder, and more tightly fitted rocks than the other two sites. What do these results tell us?

Post-driving is a dynamic process, and the reaction that occurs when the hammer hits the post depends on many factors and their interactions. The driving energy available increases with each succeeding blow, for about 40 percent more energy is delivered per stroke when the post has been driven in 3 feet than at the beginning of driving. Therefore we should expect a greater depth of penetration per blow at the end of driving than at the beginning.

When a rock in the base is hit, we assume that we are point-loading in most cases. That is, the rock will not be in contact with the entire cross-section of the post. Under point-loading, the forces acting on this rock become very great. The tendency will be to either move or break the rock or to damage the post.

Consider what happens when a steel post is driven. The I-shaped cross-section of the 6B8.5 steel post has an area of about 2.6 square inches and a perimeter of about 30 inches. In com-

parison to wood, the small cross-section is of distinct advantage in reducing the chances of hitting obstacles. But more important, perhaps, this cross-section requires relatively little displacement of aggregate for insertion.

The side surface area of the steel post is about 25 percent greater than that of a 7-inch wooden post. Resistance due to rubbing of the sides against gravel or rock can therefore be greater with the steel post.

During driving, the web of the steel post is restricted from bending or twisting by the flanges. However, the flanges are under no such restraint at their edges. The energy delivered by the driving hammer is concentrated on an obstruction by the small cross-section. In soft rock fills, such as used in this study, this concentrated loading will often break up such rocks, and the posts will pass on by. For obstacles that resist breaking, the steel post must either move the rock or become deformed. In this case, the small cross-section becomes a disadvantage. Our experience shows that the flanges are rather easily bent or twisted. Detection of this damage from observing the driving action above ground is not possible. Because deformation of the web is restricted by the flanges, damage to the web requires an excess number of blows.

When a wooden post is driven, the major consideration is displacement of the substrate. We believe the following happens. With the first few blows, the top layers are compacted beneath the post. Shearing of the topping around the post is likely. When compaction is no longer possible, cone formation begins. In profile, the cone is a wedge that compresses the substrate down and to the sides. The result is a flow of material from the base to the sides. This material is more highly compacted than that further away from the post. The result is a tightly fitted post.

The cone is considered the major reason why wooden posts, with 15 times the cross-sectional area of steel posts, took only twice as many blows to install with the 950-pound hammer on site I. The action is similar to driving a pointed post.

Another factor is the side surface area of the post. As mentioned above, the side surface area of steel is about 25 percent

greater than that of a 7-inch wooden post. When considering the influence of side surface area, we must also compare the properties of the post materials. In comparison with wood, steel is uncompressible. Wood fibers can be compressed or deformed, thus minimizing the resistance to the rock.

How can the cones penetrate the rock layers? The reasons for this are not clear. It is possible that, during impact, the cones exert compressive forces that start the displacement of rocks not yet in contact with the cones. Rocks that cannot be displaced will, of course, destroy the cones.

Summary & Discussion

Both wooden and steel posts driven under adverse conditions perform well, but wood is superior to steel in resisting damage. Of the 26 steel posts driven, 4 were moderately damaged and 3 were severely damaged. Of the 32 wooden posts driven, 23 were judged to be undamaged. Only 2 wooden posts were found to be moderately or severely damaged. This favorable comparison for wood was true even though the driving conditions for wood were generally more adverse than those for steel.

The superiority of wood is the result of its mechanical properties and of post-soil interaction during driving. Wood is extremely strong in compression parallel to the grain. One post took 72 full blows with an 800-pound hammer without damage to the top or bottom. Another post took 40 blows with a 1,200-pound hammer and suffered only very light damage.

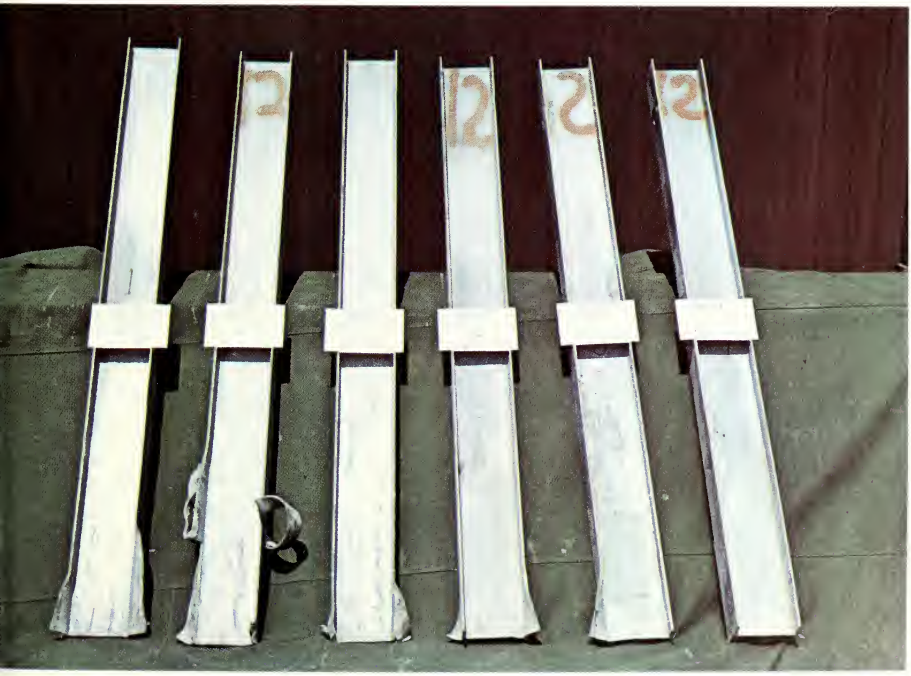
Cones of compressed top-layer material beneath flat-bottomed wooden posts reduce the energy required for insertion and protect the bottom of the posts. The presence of knots within 3 to 12 inches of the base of a wooden post further minimizes any damage that might occur.

The results on site III suggest that wood will perform even better in comparison with steel if harder rocks are found in the base. If rocks resist breaking and do not have wedge-shaped edges, the wooden posts will displace them without suffering damage.

Damage below the groundline brings up questions about the performance of guardrail systems. How often do adverse conditions occur? If we install posts on 6-foot 3-inch centers, and a severely damaged post is bracketed by two undamaged posts, how important is the damage? If a steel post is severely bent, how much damage can it sustain and still perform? If the galvanizing is scratched off during driving, what is the effect of rusting rate on rate of loss of strength? Creosote-treated wooden posts may have a service life of over 40 years. What is the effect of cracks in the treated shell of wooden posts that are located below the groundline on the rate of loss of strength?

We cannot assume that posts undamaged above the groundline are also undamaged below. None of the posts used in this study was damaged above the groundline. Also, because all posts require the same number of blows to drive, we cannot assume

Figure 9.—Six steel posts on site I required 12 blows each for insertion. Damage ranged from none to severe.



that all posts are either damaged or undamaged. Driving wood onto wedge-shaped rocks can cause splits.

Six steel posts (fig. 9) on site I each received 12 blows with a 950-pound hammer. Damage ranged from none to severe. Damage to the flanges of steel posts occurs relatively easily and is not detectable from above-ground observations of the driving action.

Conclusions

This study must be considered exploratory. We used only one wood species: southern yellow pine. Other species may perform better or worse than this material. We would expect Douglas-fir to perform as well, and many of our dense hardwoods such as red oak might perform better.

We evaluated these posts in only one type of rock-filled base: sandstone. This is a relatively soft type of rock. We assume that, had the rocks been harder and less resistant to fracture, the wooden posts would suffer less damage and the steel posts more damage than that found in this study.

We concluded that:

- The type of guardrail post should be carefully specified, depending on soil conditions. Ease of installation has little to do with performance. In soft soils, wooden posts may be preferred because of their larger soil-bearing surface. In rocky soils, wooden posts may be preferred because of their ability to resist damage. Adversely, wooden posts will occasionally disturb the berm where steel posts will not. On certain types of granular fills, steel posts may be preferred because of the minimized displacement of fill and the resulting minimized chance of severe site disturbance.
- Wooden posts are superior to steel in resisting damage below the groundline.
- The driving action causes no damage to the tops of wooden posts.

- Wooden posts should have a blunt bottom because, as they are driven, a cone of compressed top-layer material forms at their base. This cone acts as a wedge, which reduces the energy required to drive and protects the bottom of the post from damage.
- Wooden posts should be cut so that knots are located between 3 and 12 inches from the base to minimize the severity of damage.

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Seasonal Changes in CARBOHYDRATE LEVELS in roots of sugar maple

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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THE ONSET of some dieback and decline diseases has been associated with insect defoliation *(Giese et al. 1964, Staley 1965, Nichols 1968),* but tree mortality in these diseases has been associated with the added effects of agents of secondary action *(Knull 1932, Houston and Kuntz 1964, Staley 1965, Nichols 1968).*

Defoliation causes physiological changes in trees and may predispose trees to attack by pathogenic organisms *(Kozlowski 1969).* Artificial defoliation of sugar maple trees causes significant changes in carbohydrate levels in the roots *(Parker and Houston 1970).* These changes may be related to observed invasion and attack by the root pathogen *Armillaria mellea* (Vahl) Quel. of sugar maple trees weakened by defoliation *(Houston and Kuntz 1964).*

These observations on carbohydrate changes in sugar maple roots were made near the end of the growing season, and it is not known whether carbohydrate changes caused by defoliation are different from those changes that occur naturally in the spring when food reserves are mobilized for use in initial shoot growth *(Keinholz 1941).*

Jones and Bradlee *(1933)* obtained some information on seasonal changes in roots of sugar maple, but their observations were limited to one sample per month. They did not determine the concentrations of all individual carbohydrates.

This study was done to determine the normal complement of individual carbohydrates present in roots of sugar maples during

the year and to obtain, as a basis for future comparison, an estimate of the normal variation and range of concentrations of individual carbohydrates in the roots during the year.

MATERIALS AND METHODS

Dominant and codominant sugar maple trees, 5 to 12 cm. d.b.h. and 9 to 15 m. tall, growing in southern Connecticut, were used. Samples were harvested monthly from June 1969 until February 1970 and then bi-weekly until mid-May 1970. Three root lengths about 1 m. long were removed from each of five different trees on each harvest date.

Roots were excavated, cut into 15-cm. sections, put in polyethylene bags, and placed in insulated bags containing dry ice. They were transported to the laboratory and frozen at —30°C until they were analyzed.

Starch was extracted from whole root sections according to the procedure of Hassid and Neufeld *(1964)* and was measured by the method described by Siminovitch et al. *(1953)*. Standard starch solutions were prepared from starch extracted from sugar maple roots.

Only the outer wood—the tissue attacked by *A. mellea*—was analyzed for sugars. The bark was peeled from root sections, and the outermost wood was scraped off with a scalpel. Sugars were extracted with 80 percent ethanol *(Parker 1962)*. The tissue was placed with the alcohol in a cup surrounded by an icewater bath. It was comminuted twice for 4 minutes, with a "Virtis 23" homogenizer, using fresh ethanol each time. The extracted tissue was rinsed once with 80-percent ethanol. The combined extracts and rinse were filtered and evaporated to near dryness in a rotary evaporator at 39° $\pm$ 1°C and then spotted on No. 1 Whatman filter paper.

Sugars were separated on the paper with a butanol-acetic acid-water solution (4:1:5), detected with a benzidine-trichloroacetic acid-acetone spray reagent *(Linskens 1959)*, and quantified by densitometry.

Seasonal Trends

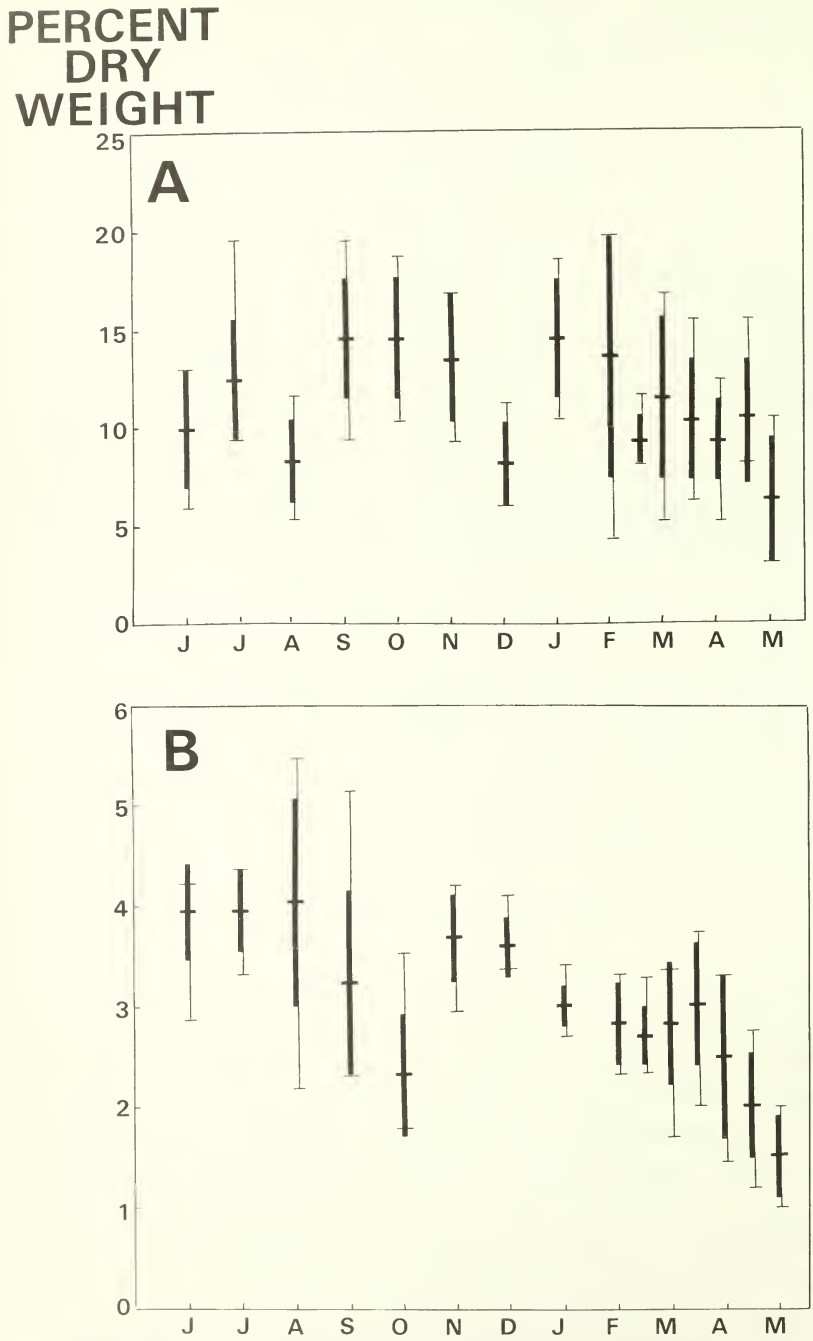
There was a definite seasonal trend in the starch content of sugar maple roots (fig. 1A). The starch level began to increase after budbreak; it increased to a maximum in late fall and began decreasing in late winter toward the spring minimum. The two low readings in August and December were probably the result of inherently low-starch trees included in the sample. These same groups of trees, in August and December 1970, had average starch contents of 9 percent though other groups of five trees sampled in August and December had average starch contents of 13 and 12 percent, respectively. The seasonal trend in sucrose concentration was generally similar to that observed for starch (fig. 1B). There appeared to be an autumn decrease in sucrose not apparent in starch. Glucose and fructose concentrations varied (figs. 1C and 1D). There was an indication of an autumn decrease in glucose and fructose similar to that observed in sucrose.

Stachyose, raffinose, and maltose, which first appeared in late summer, increased to a maximum by mid-winter and disappeared just after budbreak (figs. 2A, 2B, and 3). Stachyose concentrations remained high until mid-spring and then decreased rapidly. Raffinose and maltose slowly decreased from late winter on.

Discussion

The seasonal pattern of carbohydrate changes in roots of sugar maple observed in this study is similar, in general, to that reported by Jones and Bradlee *(1933)*. The pronounced winter increase in hexoses reported in their study was not observed in this study. This difference possibly may be due to Jones and Bradlee's use of the reducing sugar reaction to detect hexoses. Maltose, although not a hexose, yields a reducing reaction; and the increase of this sugar in the winter months (fig. 3) would account for the winter "hexose increase" found by Jones and Bradlee.

Maltose is considered to be a common constituent of the carbohydrate complex of woody plants *(Kramer and Kozlowski 1960)*.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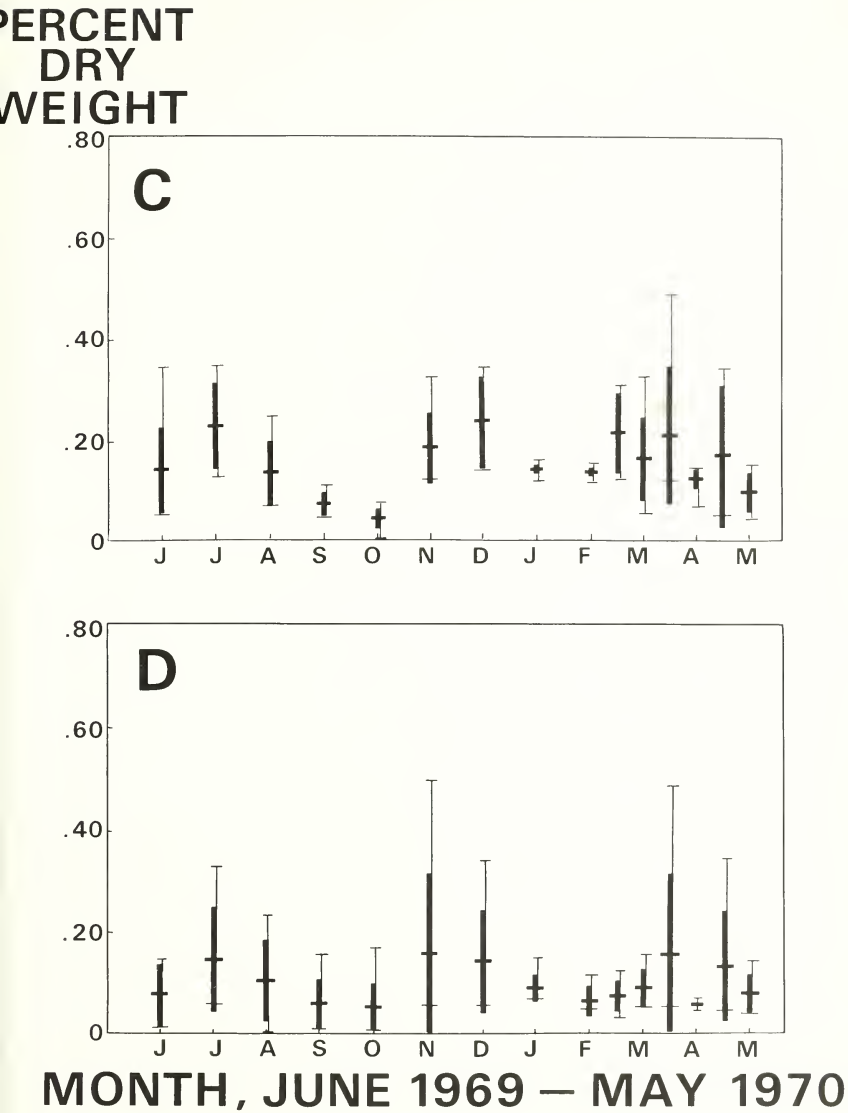
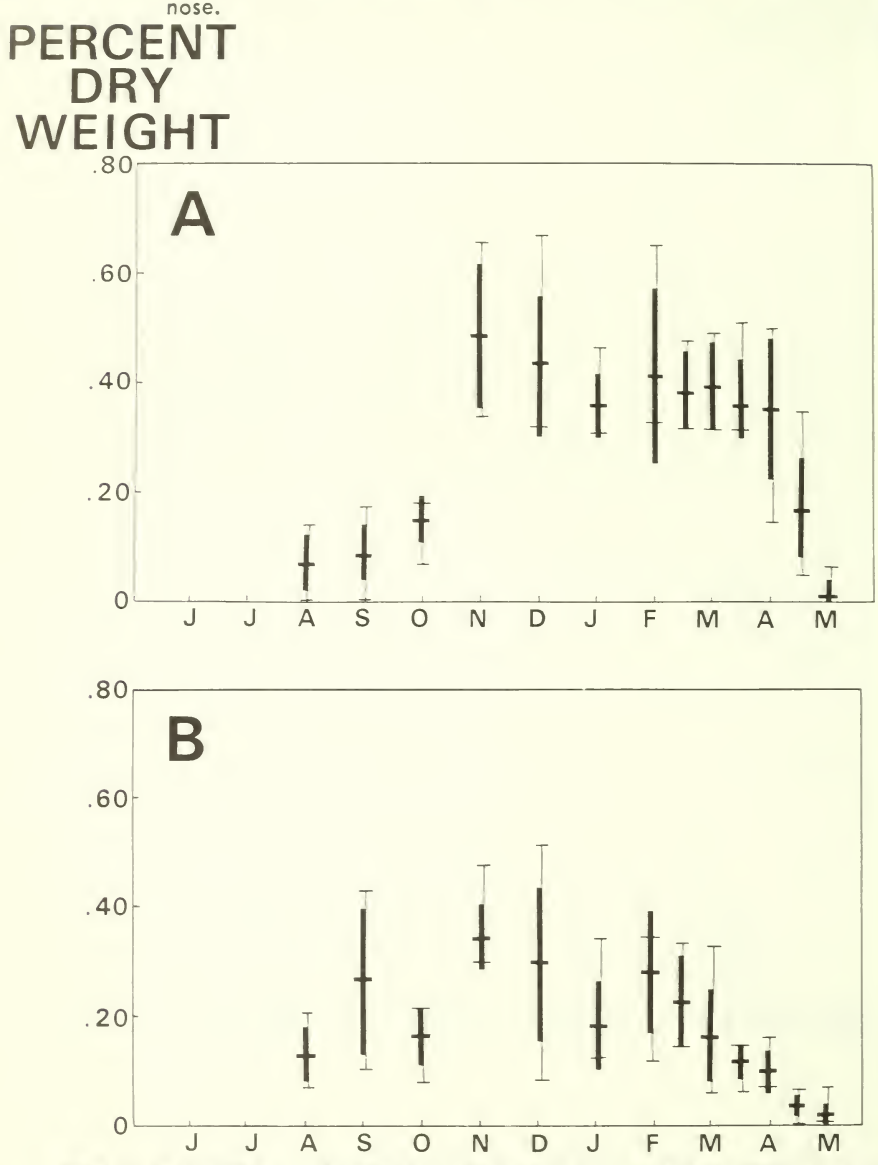


Figure 1. — Seasonal trends of carbohydrates in roots of sugar maple from June 1969 to May 1970. (A) Starch in whole roots; (B) Sucrose in outer wood; (C) Glucose in outer wood; (D) Fructose in outer wood. Range is shown by thin horizontal lines, average by heavy crossbar, and ± 2 standard errors by heavy vertical lines, for five trees each observation.

Figure 2. — Seasonal trends of carbohydrates in outer wood of roots of sugar maple. (A) Stachyose; (B) Raffinose.



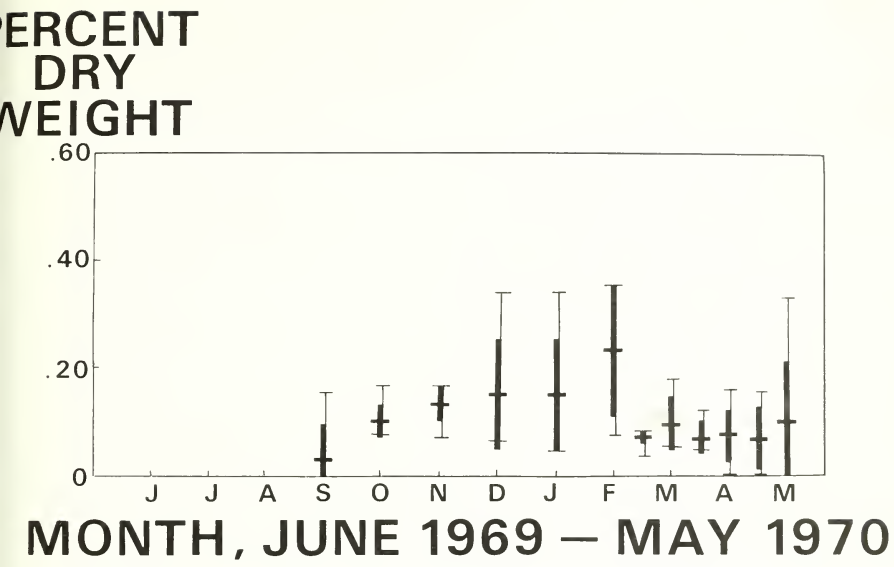


Figure 3. — Season trend of maltose in outer wood of roots of sugar maple.

However, there are no specific reports on the quantities present in woody plant tissues. Because most studies have examined reducing sugars as a group, maltose probably has been overlooked. The accumulation of maltose coincides with the winter decrease in starch content and may indicate an amylase-starch breakdown system. Amylases have been found in the sap of several maple species *(Meeuse 1952).*

Stachyose and raffinose accumulated in sugar maple roots starting in late summer and then disappeared shortly after budbreak. This phenomenon apparently is related to the onset and termination of dormancy. Seasonal variation of these sugars in conifers has been related to cold hardiness *(Parker 1957, 1959).*

The normal seasonal carbohydrate changes in sugar maple roots appear to follow a predictable pattern, and any physiological disturbance caused by defoliation or other stress factor that would alter the normal contents should be easily detected. With this seasonal data as a basis for comparison, studies to determine the effects of defoliation on tree physiology and susceptibility to pathogenic organisms can be started.

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TREE GRADES for EASTERN WHITE PINE

by Robert L. Brisbin
and David L. Sonderman

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TREE GRADES for EASTERN WHITE PINE

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FOREWORD

IN 1957 the Forest Service Log Grade Committee recommended a service-wide action program in log and tree grade research. Approval of the program late in 1958 resulted in the establishment of five species-oriented timber-quality research projects covering the several groups of commercially important timber species.

The eastern softwood timber-quality project was activated in 1960. The initial objective of the project was to develop better log and tree grades for eastern white pine. This report presents the results of the initial research on tree grades.

The authors thank the many individuals and organizations who contributed time and services in this research effort. Worthy of mention are: Regions 8 and 9 of the National Forest System; the Minnesota Agency, Bureau of Indian Affairs; the New York State University College of Forestry, Syracuse, N. Y.; the Maine Forest Service; the Northeastern Lumber Manufacturer's Association and its member mills; and the Northern Hardwood and Pine Manufacturer's Association and its member mills.

INTRODUCTION

EASTERN WHITE PINE accounts for only a small percentage of the Nation's total softwood lumber production, but it plays an important role in the overall timber economy of the Northeast, the southern Appalachians, and the Lake States. Because the quality of eastern white pine is extremely variable throughout its commercial range, an adequate tree-grading system is necessary for consistent stratification of trees into distinct value classes for appraisal and inventory purposes.

The tree-grading system presented in this report is not intended to replace the standard white pine log-grading system. To correctly apply the log grades, the ends of the log, as well as the bark surface, must be evaluated. Therefore it is impossible to apply the standard white pine log grades to portions of standing trees.

However, certain situations require that trees be evaluated instead of logs. For example, when a tract of timber is sold, some method must be used to determine an objective value of the trees in the sale. An adequate tree-grading system provides a way of estimating this value. Forest inventory is another example where a standard tree-grading system is useful for evaluating changes in timber quality over a period of time.

The only apparent record of any previous attempt to grade eastern white pine trees was a system developed in 1950 at the Pack Demonstration Forest in New York. However, it

was more of a growing-stock grading system that could be applied to trees as small as 6 inches in diameter at breast height (d.b.h.). Although it segregated trees into relative value classes, the system proved to be more of a management tool for improving growing stock. No record of performance data were available for this early system.

DEVELOPMENT OF THE SYSTEM

The development of the tree grades for eastern white pine paralleled the development of the log grades (*Ostrander and Brisbin 1971*). Most of the studies were designed and carried out so that the lumber-yield data could be related back to the tree from which it orginated. Also, tree diagrams, describing the surface characteristics of the entire tree, were made by combining all of the log diagrams for each tree. These two sets of data—the lumber-grade yields and the tree diagrams—formed the basis for the development and analysis of the tree-grading system.

A trial tree-grading system was developed from the initial lumber-grade yield study in the Northeastern area (New York and Maine) by applying a modified set of the log-grade specifications to the butt 16-foot section of the tree. Four possible tree-grading systems were developed from detailed analyses of the graded tree diagrams (See Appendix for development details). The four grading systems were all based on the application of the modified log-grade specifications to the surface of the butt section of the tree.

Tree diagrams from two additional areas—southern Appalachian and Lake States—were then graded by these four systems. Analyses of the data from each of the three areas indicated that the tree-grading system described here stratified the trees into distinct value classes and resulted in substantial and uniform differences of value among the various grades. The system also proved to be relatively easy to apply after a limited amount of training.

General Considerations

The specifications for the approved tree-grading system apply to merchantable unpruned eastern white pine trees (fig. 1). The grades are based on external characteristics of the butt 16-foot section of the tree and visual indications of

EASTERN WHITE PINE TREE GRADE SPECIFICATIONS

DING FACTOR	TREE GRADE 1	TREE GRADE 2	TREE GRADE 3	TREE GRADE 4
IINIMUM .B.H. (inches)	10	10	10	10
IAXIMUM VEEVIL IN-URY IN BUTT 6-FT. SECTION number)	None	None	2 injuries	No limit
IINIMUM FACE EQUIRE-IENTS ON UTT 16-FT. ECTION	Two full length or four 50% length good faces.[1] (In addition, knots on balance of faces shall not exceed size limitations of Grade 2 sections.)	NO GOOD FACES REQUIRED. Maximum diameter of knots on three best faces: SOUND RED KNOTS not to exceed 1/6 scaling diameter and 3 inch maximum.[2] DEAD OR BLACK KNOTS including overgrown knots not to exceed 1/12 scaling diameter and 1½ inch maximum.[2]	SOUND RED KNOTS not to exceed 1/3 scaling diameter and 5 inch maximum.[2] DEAD OR BLACK KNOTS including overgrown knots not to exceed 1/6 scaling diameter and 2½ inch maximum.[2]	Includes all trees not qualifying for Grade 3 or better and judged to have at least one-third of their gross volume in sound wood suitable for manufacture into standard lumber.
IAXIMUM WEEP OR ROOK IN UTT 16-FT. ECTION percent)	20	30	40	No limit
IAXIMUM OTAL CALING DE-UCTION IN UTT 16-FT. ECTION percent)	50	50	50	No limit

fter the tentative grade of the section is established from face examination, the section will be reduced in grade whenever ne following defects are evident:
CONKS, PUNK KNOTS, AND PINE BORER DAMAGE ON SURFACE OF SECTION[3]
Degrade one grade if present on one face.
Degrade two grades if present on two faces.
Degrade three grades if present on three or four faces.

f the final grade of the grading section is 1, 2, or 3, examine the tree for weevil njuries in the merchantable stem *above* 16 ft. If the total apparent weevil injuries xceed three, degrade the tree one grade below the section grade.[3] Otherwise the tree rade is the same as the final section grade.

under 16 inches d.b.h. require four full length good faces.
ng diameter is estimated at the top of the 16-foot grading section.
ree will be degraded below Grade 4 unless net tree scale is less than one-third of gross tree scale.

Figure 1.—Eastern white pine tree-grade specifications.

weevil damage in the upper merchantable stem. Trees must have a d.b.h. of at least 10 inches and have at least one-third of the gross volume in sound wood suitable for manufacture into standard yard lumber.

The grading system is designed to stratify trees into distinct value classes and to predict differences in lumber-grade yield of trees sawed into standard yard lumber. The lumber-grading rules of the Northeastern Lumber Manufacturer's Association and the Northern Hardwood and Pine Manufacturer's Association define the grades of standard yard lumber.

Grading Factors and Definition of Terms

The following description of grading factors and definitions of terms are presented in the same descending order as listed in the specifications. For detailed descriptions of defects and other log and tree characteristics, see Ostrander (*1971*).

(1) Tree diameter. —A tree must have at least a 10-inch d.b.h. to be graded by these specifications.

(2) Weevil injury in the grading section. — Evidence of weevil injury can be recognized by moderate to severe crook at the point of injury. At the point of injury, limbs are usually large and acute-angled. Grading sections showing none of these characteristics are considered free of weevil injury.

(3) Minimum Face Requirements on the grading section. —A face is one-fourth the circumference of the surface for the full length of the grading section. A good face is one that is free of knots of any type larger than ½ inch in diameter, overgrowths indicating larger knots, and conks or punk knots. A half face is one-half the length of the section. Good half faces must be in either the butt or top half of the grading section.

Sound red knots are any visible branches, stubs, or sock-

ets that resulted from living branches or branches that have been dead for a short time. They are intergrown with the surrounding wood and contain no rot. The average diameter of sound red knots is measured at the point where the limb would normally be trimmed from the main stem. Knot size is determined by measuring only the diameter of the red heartwood portion of the knot.

Dead or black knots are visible branches, stubs, or sockets that do not conform to the definition of sound red knots. The average diameter of dead knots is measured at the same point as the sound red knots; however, the total limb diameter is considered rather than just the red heartwood portion.

Overgrown knots are identified by a distinctive circular or elliptical pattern in the bark and are treated the same as dead knots. The size of the branch stub underlying the overgrowth can be estimated by observing the adjacent visible knots.

(4) Maximum sweep or crook allowance in the grading section.—Sweep is the gradual deviation in inches of the longitudinal axis from a straight line connecting the centers of each end of the grading section. Crook is an abrupt curve or bend deviating from the straight longitudinal axis of the section. Although sweep and crook are normally considered as scaling deductions, they also may cause lumber degrade and therefore must be treated as grading factors. For grading purposes, the amount of sweep or crook present in the grading section is calculated by the following two formulas described by Grosenbaugh (1952):

$$\text{Percent sweep} = \frac{\text{Sweep (inches) minus 2}}{\text{Section scaling diameter (inches)}} \times 100$$

$$\text{Percent crook} = \frac{\text{Deviation (inches)}}{\text{Section scaling diameter}} \times \frac{\text{Section affected length (feet)}}{16} \times 100$$

(5) Maximum total scaling deduction in the grading section.—The total scaling deduction includes sweep and crook deductions as well as deductions for other scalable defects

in the grading section. For grading purposes, the amount of scalable defect must be expressed as a percent of gross volume.

(6) Conks, punk knots, and borer damage on the grading section.—A conk is a fruiting body of a wood rotting fungus (generally *Fomes pini* in eastern white pine). A punk knot is completely rotten, and the brown mycelial mass of the rot fungus is visible within the knot. Pine borer damage can be recognized by entrance channels (holes 3/16 to 1/2 inch in diameter) on the bark surface.

(7) Weevil damage in the upper merchantable stem.—Weevil injuries in the upper stem can be recognized by severe crook and by large acute-angled branches at the point of injury.

Application Procedure

Trees are graded in one or two steps. First, a tentative grade is established for the butt 16-foot section, using factors 1 through 6 of the tree grade specifications (fig. 1). If the tentative grade of the grading section is grade 4, no further examination is necessary; the tree is a grade 4. However, if the tentative grade of the butt 16-foot section is 1, 2, or 3, examine the upper merchantable stem for weevil injuries. If the total apparent weevil injuries exceed three, degrade the tree one grade below that of the tentative grade.

PERFORMANCE OF THE GRADING SYSTEM

Lumber-grade recovery yields for each tree grade are necessary for estimating the value of trees that have been graded by this system. Percent lumber-grade yields for each sample area and tree grade were developed from regression analysis, using combinations of d.b.h. and merchantable height as independent variables. The tabulated lumber-grade

recoveries for each tree grade show the expected percent volume of each standard lumber grade by various d.b.h. and merchantable height combinations (tables 1 through 12).

Separate performance tables for each geographic area are presented because of the different lumber-grading systems in use and because of the much higher incidence of weevil injury in the Northeast area as compared to the southern Appalachian area. The difference in lumber yields between the Northeast area and southern Appalachian area are particularly evident in tree grades 3 and 4. A higher incidence of weevil injury accounts for the significantly higher proportion of No. 4 Common lumber in grade 3 trees of the Northeast sample. The Lake States sample has a significantly greater proportion of No. 1 and 2 Common lumber in all four tree grades as compared to either the Northeast or southern Appalachian samples. This is because the Lake States use a different lumber-grading rule.

The curved lumber-grade yields are an average estimate for each geographic area. Therefore it is not likely that they will precisely predict the output of any particular mill. Because sawing patterns and lumber thicknesses may vary from mill to mill, users of these grades should develop performance data that are specifically tailored to their particular set of conditions.

The recovery tables for the Northeast area reflect the performance of trees from ten different timber stands in New York and Maine. The logs from these trees were sawed into 4/4 standard yard lumber at three circular sawmills. The recovery tables for the southern Appalachian area are based on trees from seven different timber stands in southern North Carolina and northern Georgia. They were sawed at one circular mill. Both 4/4 and 8/4 standard yard lumber were produced. In both the Northeast and southern Appalachian areas, the lumber was graded according to the rules of the Northeastern Lumber Manufacturer's Association.

In the Lake States area, trees from six medium-to-old-growth stands in Minnesota and Michigan were converted

into 4/4 and 8/4 standard yard lumber at two band sawmills. The lumber was graded by the rules of the Northern Hardwood and Pine Manufacturer's Association.

The distribution of the sample trees by d.b.h. and tree grade in each area (table 13) is an indication of the relative precision of the lumber-grade recovery tables. In the Northeast and Lake States areas, very few sample trees were larger than 28 inches d.b.h. Most of the trees in the southern Appalachian sample were smaller than 34 inches d.b.h., although a few trees were in the 36- and 38-inch d.b.h. class.

In the Northeast and Lake States areas, a substantial price differential by board width exists within several lumber grades. Because of this, the distribution of lumber widths in each lumber grade and tree d.b.h. class is important. We found a substantial difference in lumber width-class distribution between the select and combined common grades of lumber (table 14). Tree grade or merchantable height did not significantly affect width-class distribution after tree d.b.h. and lumber grade were considered. The distribution percentages can be applied to the curved yields to provide an estimate of the lumber-grade yields by width class.

To effectively use the lumber-grade yield tables for estimating lumber recovery, tree overruns must be developed to convert tree-scale volume to lumber-tally volume. Tree overruns depend on several factors such as the volume table used to estimate gross tree volume, the type of scaling procedures used to estimate net tree volume, the type of sawmill used to convert the trees to lumber, and the size and mix of products produced from the trees.

We have computed the overruns by the International ¼-inch log rule for each of the three sample areas (table 15). Overruns by the Scribner Decimal C log rule were computed for only the southern Appalachian and Lake States samples (table 15). These overruns are based on the sum of the net *log* scales and lumber-tally volumes for each tree, not on a net tree scale estimated from a tree-volume table. Many different types of tree-volume tables and methods of arriv-

ing at net tree scale are in use; therefore, we felt that summing the net log-scale volumes within a tree would provide a more common base.

In the Northeast area, the overruns represent an average of three circular sawmills. The overruns for the southern Appalachian and Lake States samples are based on one and two mills, respectively. Because of the numerous factors affecting overrun, users of the system should develop their own overrun values.

SUMMARY

The standard Forest Service grades for eastern white pine trees presented in this report resulted from many years of research and cooperative effort from the lumber industry. This grading system is recommended for use by timber buyers, sellers, and processors throughout the commercial range of eastern white pine.

The lumber-grade yield tables in this report represent the performance of better-than-average sawmills in the respective geographic areas, but may not predict precisely any particular mill's output because of differences in lumber thicknesses and sawing patterns. Therefore, it is recommended that users of this grading system conduct mill-scale studies at their own mills, thus assuring more precise estimates of lumber-grade yields by tree grade. Both lumber-grade yields and overrun factors can be developed from the same mill-scale study.

APPENDIX I

PERFORMANCE TABLES

Tables 1-12.—Curved white pine lumber grade yields

Table 13.—Distribution of trees in each sample area by tree grade and d.b.h. class

Table 14.—Lumber width-class distribution by lumber grade and d.b.h. class

Table 15.—Percent overruns of the International ¼-inch and Scribner Decimal C rules by d.b.h. for each sample area

Table 1.—Curved white pine lumber grade yields, in percent

[Basis: 71 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		1-LOG TREES			
10	18	44	32	6	0
12	23	35	32	10	0
14	26	28	33	13	0
16	28	24	32	16	0
18	30	20	33	17	0
		2-LOG TREES			
10	15	38	34	13	0
12	19	30	34	17	0
14	23	24	33	20	0
16	25	20	32	22	1
18	27	17	32	23	1
20	28	14	33	24	1
22	30	13	31	25	1
24	31	11	31	26	1
		3-LOG TREES			
12	16	25	36	23	0
14	19	20	34	26	1
16	21	16	34	28	1
18	23	13	34	29	1
20	25	11	33	30	1
22	26	10	31	31	2
24	27	9	31	31	2
26	28	8	30	32	2
		4-LOG TREES			
14	16	15	36	32	1
16	18	12	35	34	1
18	20	10	34	34	2
20	21	8	33	36	2
22	23	7	32	36	2
24	24	7	31	36	2
26	24	6	30	38	2
28	25	6	29	37	3

Table 2.—Curved white pine lumber grade yields, in percent

[Basis: 41 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		1-LOG TREES			
10	7	20	53	19	1
12	8	22	47	22	1
14	9	23	43	25	0
16	9	23	42	26	0
18	10	23	39	28	0
		2-LOG TREES			
10	7	16	52	24	1
12	8	17	47	27	1
14	9	18	42	30	1
16	10	18	39	32	1
18	10	18	37	34	1
20	11	17	36	35	1
22	11	17	34	36	2
24	12	17	32	37	2
		3-LOG TREES			
12	8	13	46	33	0
14	9	13	41	36	1
16	10	13	38	38	1
18	11	12	36	39	2
20	11	11	34	42	2
22	12	10	32	43	3
24	12	9	31	45	3
26	13	8	30	45	4
		4-LOG TREES			
14	9	8	41	41	1
16	10	7	37	44	2
18	11	6	35	46	2
20	12	5	33	47	3
22	12	4	31	49	4
24	13	2	30	50	5
26	13	1	28	52	6
28	14	0	27	53	6

Table 3.—Curved white pine lumber grade yields, in percent

[Basis: 59 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		1-LOG TREES			
10	3	7	43	43	4
12	3	5	40	48	4
14	3	4	38	51	4
16	3	3	37	53	4
18	4	3	36	53	4
		2-LOG TREES			
10	3	5	41	46	5
12	3	4	38	50	5
14	3	3	36	53	5
16	4	3	34	54	5
18	4	2	33	56	5
20	4	2	32	57	5
22	5	2	31	57	5
24	5	3	30	58	4
		3-LOG TREES			
12	3	2	35	53	7
14	3	2	33	55	7
16	4	2	31	57	6
18	4	2	30	58	6
20	5	2	29	58	6
22	5	2	28	60	5
24	6	3	27	59	5
26	6	3	26	60	5
		4-LOG TREES			
14	3	1	30	58	8
16	4	1	28	60	7
18	5	1	27	60	7
20	5	2	26	61	6
22	6	2	25	61	6
24	6	3	24	62	5
26	7	4	23	61	5
28	8	4	22	62	4

Table 4.—Curved white pine lumber grade yields, in percent

[Basis: 49 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		1-LOG TREES			
10	2	2	19	52	25
12	1	1	17	61	20
14	1	1	16	66	16
16	1	0	15	70	14
18	1	0	14	73	12
		2-LOG TREES			
10	1	3	23	55	18
12	1	2	21	62	14
14	1	1	20	66	12
16	2	1	19	67	11
18	2	1	18	69	10
20	2	1	18	68	11
22	2	0	17	70	11
24	2	0	17	68	13
		3-LOG TREES			
12	1	3	25	63	8
14	2	2	24	65	7
16	2	2	23	65	8
18	2	1	22	66	9
20	2	1	21	66	10
22	2	1	21	64	12
24	3	1	20	61	15
26	3	0	20	60	17
		4-LOG TREES			
14	2	3	28	64	3
16	2	2	27	64	5
18	2	2	26	63	7
20	3	2	25	60	10
22	3	1	25	58	13
24	3	1	24	55	17
26	4	1	24	50	21
28	4	1	23	47	25

Table 5.—Curved white pine lumber grade yields, in percent

[Basis: 103 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
12	20	30	33	17	0
14	22	23	33	22	0
16	23	18	33	26	0
18	24	15	32	29	0
20	26	12	31	31	0
		3-LOG TREES			
12	16	28	37	19	0
14	18	22	36	24	0
16	20	17	35	28	0
18	22	14	34	30	0
20	23	11	33	32	1
22	24	9	32	34	1
24	25	7	31	35	2
26	26	6	29	37	2
		4-LOG TREES			
14	15	20	39	26	0
16	17	16	37	29	1
18	18	12	37	32	1
20	20	10	34	34	2
22	21	8	33	35	3
24	22	7	31	37	3
26	23	5	30	38	4
28	24	5	28	38	5
30	25	4	26	39	6
		5-LOG TREES			
16	14	14	40	31	1
18	15	11	39	33	2
20	17	9	36	35	3
22	18	7	34	37	4
24	20	6	32	37	5
26	21	5	30	38	6
28	22	4	28	39	7
30	23	4	25	39	9
32	24	4	23	39	10
34	25	4	21	39	11

Table 6.—Curved white pine lumber grade yields, in percent

[Basis: 57 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
12	8	18	47	27	0
14	8	17	44	31	0
16	9	16	40	35	0
18	9	15	39	37	0
20	10	15	37	38	0
		3-LOG TREES			
12	6	16	47	29	2
14	7	15	42	34	2
16	7	14	40	37	2
18	8	13	38	39	2
20	9	12	36	42	1
22	9	12	35	42	2
24	10	11	34	43	2
26	10	11	33	44	2
		4-LOG TREES			
14	5	13	42	36	4
16	6	12	39	39	4
18	7	11	37	41	4
20	7	10	36	43	4
22	8	9	34	45	4
24	9	9	33	45	4
26	9	8	32	46	5
28	10	7	31	47	5
30	11	7	30	47	5
		5-LOG TREES			
16	4	9	39	42	6
18	5	8	37	44	6
20	6	7	35	45	7
22	7	7	34	45	7
24	8	6	32	47	7
26	9	5	31	47	8
28	9	4	31	48	8
30	10	4	30	48	8
32	11	3	29	48	9
34	11	2	29	49	9

Table 7.—Curved white pine lumber grade yields, in percent

[Basis: 57 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
12	3	7	43	43	4
14	3	6	44	44	3
16	3	5	44	45	3
18	3	4	44	47	2
20	4	3	43	48	2
		3-LOG TREES			
12	3	9	42	42	4
14	3	8	42	44	3
16	3	7	41	46	3
18	4	6	41	46	3
20	4	5	40	48	3
22	4	4	39	50	3
24	4	3	38	51	4
26	5	2	36	53	4
		4-LOG TREES			
14	3	10	40	44	3
16	3	9	39	46	3
18	4	8	38	47	3
20	4	6	37	49	4
22	4	5	35	51	5
24	5	4	33	53	5
26	5	3	31	55	6
28	6	2	30	55	7
30	6	1	28	57	8
		5-LOG TREES			
16	3	11	37	46	3
18	4	9	35	48	4
20	4	8	33	50	5
22	5	7	31	51	6
24	5	5	29	54	7
26	6	4	26	56	8
28	6	3	24	58	9
30	7	2	22	58	11
32	7	0	19	62	12
34	8	0	16	63	13

Table 8.—Curved white pine lumber grade yields, in percent

[Basis: 15 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
12	1	2	19	53	25
14	2	1	18	56	23
16	2	1	18	57	22
18	2	0	17	60	21
20	2	0	17	60	21
		3-LOG TREES			
12	2	3	21	56	18
14	2	2	20	59	17
16	2	2	20	59	17
18	2	1	20	60	17
20	2	1	19	60	18
22	2	0	19	61	18
24	2	0	19	60	19
26	3	0	19	57	21
		4-LOG TREES			
14	2	3	22	61	12
16	2	3	22	61	12
18	3	2	22	60	13
20	3	2	22	59	14
22	3	1	22	58	16
24	3	1	22	57	17
26	3	1	22	55	19
28	3	0	23	53	21
30	3	0	23	51	23
		5-LOG TREES			
16	3	4	24	62	7
18	3	3	24	61	9
20	3	3	24	59	11
22	3	2	24	58	13
24	3	2	25	55	15
26	4	2	25	51	18
28	4	1	26	49	20
30	4	1	26	46	23
32	4	1	27	42	26
34	4	1	27	39	29

Table 9.—Curved white pine lumber grade yields, in percent

[Basis: 38 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
10	4	77	17	0	2
12	9	59	22	8	2
14	13	48	24	14	1
16	16	38	26	19	1
18	19	29	28	23	1
20	21	23	30	25	1
		3-LOG TREES			
12	6	67	20	5	2
14	10	54	23	11	2
16	14	43	25	16	2
18	16	37	26	19	2
20	19	30	27	22	2
22	21	25	27	25	2
24	22	20	29	27	2
26	24	16	29	29	2
		4-LOG TREES			
14	7	61	22	8	2
16	11	50	24	13	2
18	14	43	25	16	2
20	16	37	26	19	2
22	18	32	26	22	2
24	20	26	27	24	3
26	22	23	26	26	3
28	24	19	27	27	3
30	25	16	27	29	3
		5-LOG TREES			
14	4	68	21	5	2
16	8	58	22	10	2
18	11	51	23	13	2
20	14	43	24	16	3
22	16	38	24	19	3
24	18	33	25	21	3
26	20	28	25	23	4
28	22	25	25	24	4
30	24	22	24	26	4
32	26	18	24	27	5

Table 10.—Curved white pine lumber grade yields, in percent

[Basis: 65 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
10	0	40	32	20	8
12	3	34	32	23	8
14	6	30	31	25	8
16	8	27	31	27	7
18	10	24	31	28	7
20	12	22	31	29	6
		3-LOG TREES			
12	1	37	32	21	9
14	4	33	32	23	8
16	7	29	31	25	8
18	8	26	32	27	7
20	10	23	33	28	6
22	11	21	33	30	5
24	12	19	33	31	5
26	13	17	34	32	4
		4-LOG TREES			
14	2	34	33	22	9
16	5	30	33	24	8
18	7	27	33	26	7
20	8	24	35	27	6
22	10	21	35	29	5
24	11	19	36	30	4
26	12	17	36	32	3
28	13	15	37	33	2
30	14	13	37	34	2
		5-LOG TREES			
14	1	36	33	20	10
16	3	32	33	23	9
18	5	28	34	25	8
20	7	25	35	27	6
22	8	22	37	28	5
24	9	19	38	30	4
26	11	17	38	31	3
28	12	15	38	33	2
30	12	12	42	34	0
32	13	10	41	36	0

Table 11.—Curved white pine lumber grade yields, in percent

[Basis: 30 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
10	0	15	14	56	15
12	3	13	19	52	13
14	6	10	23	49	12
16	8	8	26	47	11
18	9	6	29	47	9
20	10	3	30	49	8
		3-LOG TREES			
12	2	26	20	34	18
14	4	23	24	33	16
16	6	19	27	33	15
18	7	16	29	35	13
20	8	12	30	38	12
22	9	9	31	41	10
24	10	5	32	44	9
26	10	2	33	47	8
		4-LOG TREES			
14	2	34	25	18	21
16	4	30	27	20	19
18	5	26	29	23	17
20	6	21	31	27	15
22	7	17	31	32	13
24	8	12	32	36	12
26	8	8	33	41	10
28	8	3	33	48	8
30	8	0	33	53	6
		5-LOG TREES			
14	0	48	25	2	25
16	2	41	28	6	23
18	3	37	29	11	20
20	4	31	30	17	18
22	5	25	31	23	16
24	5	19	32	30	14
26	6	14	32	36	12
28	6	8	32	44	10
30	6	3	32	51	8
32	6	0	31	58	5

Table 12.—Curved white pine lumber grade yields, in percent

[Basis: 36 trees]

D.b.h. (inches)	Select	No. 1-2 Common	No. 3 Common	No. 4 Common	No. 5 Common
		2-LOG TREES			
10	1	14	27	45	13
12	2	11	25	48	14
14	3	9	23	52	13
16	4	7	22	54	13
18	5	5	22	56	12
20	5	3	22	59	11
		3-LOG TREES			
12	1	22	22	32	23
14	2	19	21	36	22
16	3	16	21	39	21
18	4	14	21	41	20
20	5	12	21	43	19
22	6	9	21	47	17
24	6	7	22	49	16
26	7	5	23	51	14
		4-LOG TREES			
14	1	29	19	20	31
16	2	26	19	24	29
18	3	22	19	27	29
20	4	20	20	30	26
22	5	17	21	33	24
24	6	14	22	36	22
26	7	11	23	40	19
28	8	9	24	42	17
30	8	6	25	46	15
		5-LOG TREES			
14	0	39	16	5	40
16	1	35	17	9	38
18	3	31	18	13	35
20	4	28	19	17	32
22	5	24	20	21	30
24	6	21	21	24	28
26	7	18	23	27	25
28	8	14	25	31	22
30	9	11	26	35	19
32	10	8	28	38	16

Table 13.—Distribution of trees in each sample area by tree grade and d.b.h.

[Number of trees]

D.b.h. (inches)	Northeast sample, tree grade—				Southern sample, tree grade—				Lake States sample, tree grade—			
	1	2	3	4	1	2	3	4	1	2	3	4
10	1	5	8	6	1	4	7	4	—	2	1	3
12	2	7	10	3	3	7	6	—	1	4	5	1
14	4	10	7	7	4	13	8	1	4	10	1	4
16	10	5	10	6	13	7	5	—	3	10	3	6
18	18	3	5	9	20	4	5	2	10	12	3	4
20	10	5	8	5	13	4	4	—	6	11	3	5
22	11	2	4	7	13	4	8	3	4	7	2	1
24	10	4	5	4	15	4	4	1	5	4	7	3
26	3	—	2	1	8	3	4	1	2	2	2	1
28	2	—	—	1	5	2	1	1	2	3	1	4
30	—	—	—	—	4	3	1	2	—	—	1	2
32	—	—	—	—	1	1	3	—	—	—	1	—
34+	—	—	—	—	3	1	1	—	1	—	—	2
Total	71	41	59	49	103	57	57	15	38	65	30	36

Table 14.—Lumber width class distribution by lumber grade and d.b.h. class[1]

[In percent]

D.b.h. (inches)	D-Select & Better width class:			No. 1 through 5 Common width class:		
	1	2	3	1	2	3
10	93	7	0	40	60	0
12	66	32	2	28	68	4
14	48	39	13	21	61	18
16	35	44	21	15	56	29
18	26	46	28	11	52	37
20	20	48	32	8	48	44
22	15	48	37	6	44	50
24	12	48	40	5	41	54
26	11	46	43	4	38	58
28	10	45	45	4	35	61
30	9	43	48	3	33	64
32	9	41	50	3	30	67
34	10	39	51	4	27	69

[1] Width class 1—(3 to 5 inches); width class 2—(6 to 9 inches); width class 3—0 inches and wider).

Table 15.—Percent overruns of the International 1/4-inch and Scribner Decimal C rules by d.b.h. for each sample area[1]

D.b.h. (inches)	Northeast sample		Southern sample			Lake States sample		
	Trees	International overrun	Trees	International overrun	Scribner overrun	Trees	International overrun	Scribner overrun
	No.	Pct.	No.	Pct.	Pct.	No.	Pct.	Pct.
10	20	1.9	—	—	—	6	9.2	29.3
12	22	1.6	1	1.5	11.1	11	5.4	32.8
14	28	1.4	8	1.2	22.5	19	10.4	28.9
16	31	2.0	7	—0.3	17.7	22	11.7	34.5
18	35	0.7	8	—3.8	11.7	29	11.6	32.3
20	28	0.6	4	—1.4	15.3	25	9.8	27.1
22	24	1.9	13	—3.7	8.6	14	9.6	23.9
24	23	—0.5	11	—5.4	4.4	19	11.5	24.9
26	6	0.4	12	—3.1	5.7	7	5.4	13.6
28	3	1.0	7	—2.0	6.2	10	7.1	15.1
30	—	—	10	—0.9	6.0	3	9.0	15.3
32	—	—	5	—4.8	—1.1	1	14.6	18.3
34	—	—	2	—5.8	—0.4	—	—	—

[1] The values in this table were calculated by summing the net log scales and lumber tally for each tree by 2-inch d.b.h. classes and then computing a separate overrun for each 2-inch class. These values have not been curved.

APPENDIX II

DEVELOPMENT AND TESTING OF THE GRADING SYSTEM

Several standards were followed in developing and testing this grading system (*Newport et al. 1958*). These standards include:

1. The grades in a grading system must group the trees so that variability in value or product yields is reduced to a reasonable limit.
2. For a given tree size, one grade should differ from another by not less than 10 percent of the mean value of the higher of the two grades under consideration. The differences in mean value among the several grades should be approximately equal.
3. There should be no more than six grades in any grading system.
4. A grading system should be applicable to a particular species over its commercial range.

The initial study for developing white pine tree grades consisted of a sample of 220 trees from northeastern New York and southwestern Maine (fig. 2). Size measurements were made on each tree before felling, and then the surface characteristics of each log cut from the trees were recorded on diagram sheets before the logs were processed into lumber (*Ostrander et al. 1964*).

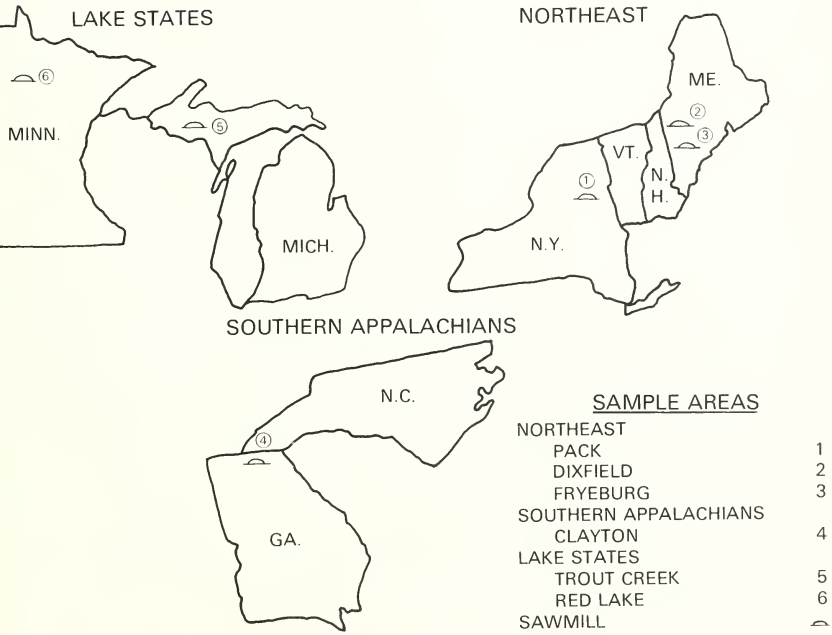

Figure 2.—Location of sample areas and study sawmills.

The total value of each tree and the board-foot volumes by lumber grade were computed by summing all log values and volumes for each tree. Then the tree diagrams were examined, and a grade was assigned to each tree, based on the grade of the best 12-foot section of the butt log. A modified version of the eastern white pine log grades was used to grade the best 12-foot section of the butt log. All of the grading factors in the log-grade specifications were considered except the log end defect factor. Analysis of tree value by the assigned tree grade showed that several grade 1, 2, and 3 trees were considerably below the average value for their respective grade. Further examination of the tree diagrams showed that these trees had several weevil injuries above the graded portion of the tree. A detailed analysis of weevil injuries indicated that grade 1, 2, or 3 trees with four or more weevil injuries in the upper merchantable stem should be degraded one grade.

After the effects of weevil injury in the upper stem were considered, a few grade 1 and 2 trees were still relatively low in value. Diagram analysis showed that if these trees had been graded on a 16-foot section basis rather than on the best 12-foot section basis, they would have been one grade lower. We also found that small grade 2 trees (10 inches to 15 inches d.b.h.) that were degraded only because of diameter limitations actually had higher values than many grade 1 trees.

From the previously described observations and analyses, we developed four possible trial grading systems for further testing:

Trial 1.—The tree grade was based on the grade of the best 12-foot section of the butt log with a minimum d.b.h. of 16 inches for grade 1 trees.

Trial 2.—This was the same as trial 1 except there was no minimum d.b.h. limitation on grade 1 trees.

Trial 3.—The tree grade was based on the grade of the full 16-foot section, with a minimum d.b.h. of 16 inches for grade 1 trees.

Trial 4.—This was the same as trial 3 except there was no minimum d.b.h. limitation on grade 1 trees.

In all four systems, grade 1, 2, and 3 trees were degraded one grade if four or more weevil injuries occurred in the merchantable stem above the grading section.

At this point in the analysis, the tree diagrams from the Northeastern sample, the southern Appalachian sample, and the Lake States sample were graded by the four trial systems. Quadratic regression equations of tree value over tree volume were then computed for each tree grade within each of the four trial systems. Residual variance of value around the regressions was pooled for each of the trial systems. The coefficient of variation at the average volume for each tree grade was also computed.

In the Northeast sample, the variance of grade 1 trees was reduced about 10 percent by eliminating the diameter-limit specification. By grading the full 16-foot section of the butt log, the variances of grades 1 and 2 were further reduced. The pooled variance for the trial 4 system was the lowest. In the southern Appalachian sample, the tree grades based on the full 16-foot section resulted in the lowest pooled within-grade variance. The diameter-limit specification did not have any effect on the trees in the southern Appalachian sample because there were very

few small grade 1 trees. In the Lake States sample, the trial 4 system resulted in the lowest pooled within grade variance and the most uniform coefficients of variation.

Estimated values per 1,000 board feet at selected volumes of lumber recovered were calculated from the regression equations. These values showed that the trial 4 system resulted in the largest and most uniform differences in value among the tree grades.

This grading system has been tested on an independent sample of 75 trees from the Northeast area. The trees were graded by the trial 4 system; then they were sawed into standard yard lumber at a circular sawmill in southern Maine. Lumber-grade volumes and values of the 75 trees were estimated by using the performance tables for the Northeast area shown in this report. The average difference between the actual and estimated value was about 3 percent of the actual value. The detailed results of this test of both the standard tree grades and the standard log grades will be reported in a separate publication.

■

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Distribution of MAPLE STRIP FLOORING in 1969

by William C. Miller

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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FOREWORD

This paper is the second in a series on the residential and commercial hardwood flooring industry. Unlike the first paper in the series, which dealt with oak strip flooring industry, this paper analyzes several qualitative questions pertaining to the maple flooring industry. The next paper planned for this series will analyze quantitative as well as qualitative information about the hardwood parquet flooring industry.

Knowing the Industry

PRODUCT DISTRIBUTION and merchandising are vital steps in the marketing of any product. Maple strip flooring is no exception. Members of the industry can benefit from general knowledge of the industry as well as from knowledge of practices of individual members. So we conducted a study to determine the distribution patterns and merchandising practices of the maple strip flooring industry, including sales and advertising policies.

On the whole, the wood flooring industry is a composite of specialized industries. In one sense, the industry consists of a residential flooring segment and an industrial flooring segment; in another sense, it consists of an oak flooring segment and a maple flooring segment; and, in still another sense, it consists of a strip flooring products segment and a block (or parquet) products segment. The subject of this paper, the maple strip flooring segment, comprises 6 percent of the total industry and consists of 1 percent residential products and 99 percent institutional, commercial, and industrial products.

Data Collection

SURVEY PROCEDURE

A questionnaire was mailed to all manufacturers of residential and/or commercial hardwood flooring on 27 January 1970; and two follow-up mailings were made at 3-week intervals to nonrespondents. Finally, nonrespondents were contacted by telephone. The following response was obtained:

Response	*No.*
Firms completed and returned the questionnaire	15
Firms completed a part of the questionnaire	2
Firm did not manufacture maple flooring in 1969	1
Total number of firms contacted	18
Total number of firms producing maple flooring	17

DEFINITION OF TERMS

Geographic Regions.—The nine regions used are those established by the Bureau of Census (fig. 1).

Production Region.—A production region is the region in which the flooring was manufactured and from which it was shipped.

Channels of Distribution.—Six channels are recognized as follows: (1) Builders, (2) Flooring subcontractors, (3) Retailers, (4) Wholesalers, (5) Nonstocking wholesalers, (6) Agents and brokers.

Figure 1. — Regions.

Results

Data was obtained on shipments of 27,269,500 bd. ft., which represents about 98 percent of the total United States maple strip flooring shipments during 1969. About 6,586,000 bd. ft.[1] of maple strip flooring imported into the United States during 1969 was not included in this study.

The study information is based on the manufacturers' records of flooring shipments through the first transaction in the distribution process.

PHYSICAL DISTRIBUTION

Production

We separated hard maple strip flooring manufacturers into two groups, northern and southern, to avoid disclosure of confidential information. Northern includes the geographic production regions of Middle Atlantic and East North Central Regions; Southern includes South Atlantic, East South Central, and West North Central Regions (fig. 2).

Northern producers—except for one manufacturer who manufactures primarily oak strip flooring—produced about 5 percent oak and 95 percent maple strip flooring. These producers accounted for about 85 percent of the total maple strip flooring and were located principally in the States of Wisconsin, Michigan, and New York (fig. 3, tables 1 through 4).

Southern manufacturers produced about 90 percent oak and 10 percent maple strip flooring and accounted for about 15 percent of the total maple strip flooring. They were located primarily in the States of Tennessee, Virginia, West Virginia, North Carolina, and Missouri.

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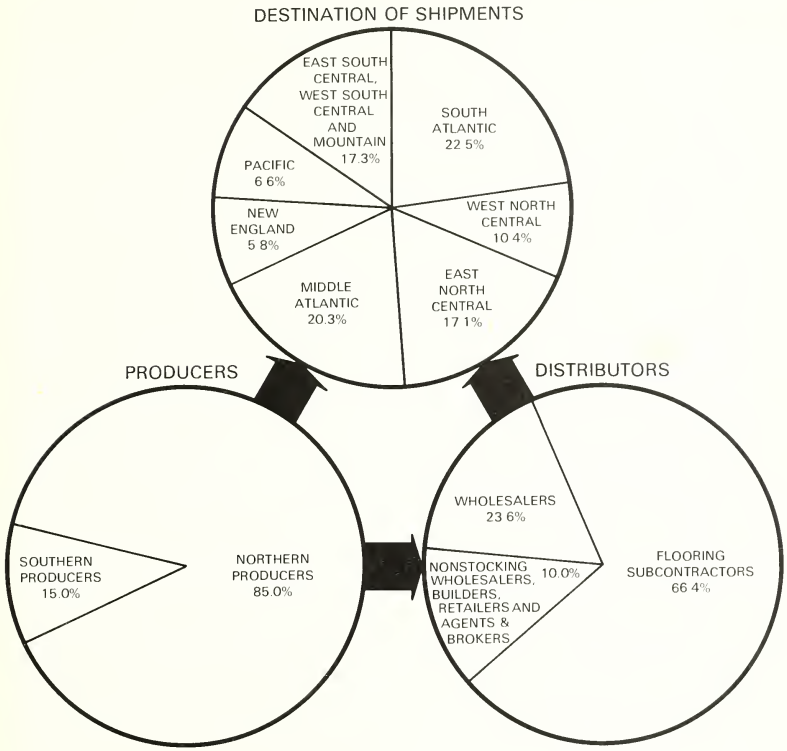
[1] U.S. Department of Commerce. U.S. Imports for Consumption and General Imports TSUSA, 1969. p. 69, Foreign Trade Division, Bureau of Census, Washington, D.C., 1970.

Interregional movement of maple strip flooring shipments by individual production region could not be discussed without disclosing confidential information on individual firms.

Northern. —Northern manufacturers accounted for 85 percent (23,171,700 bd. ft.) of the total maple flooring shipments of the United States (fig. 3, tables 1 and 2). Of this amount, flooring subcontractors distributed 76 percent; wholesalers, 17 percent; nonstocking wholesalers, 3 percent; builders, 2 percent; retailers, 1 percent; and agents and brokers, 1 percent. Shipments from the northern manufacturers were distributed to the regions as follows: South Atlantic—17 percent; West North Central—12 percent; West South Central—9 percent; Pacific—7 percent; New Eng-

Figure 2. — Geographic divisions.

Figure 3. — Producers, distributors, and destination of shipments of maple strip flooring during 1969.



land—6 percent; East South Central—6 percent; and Mountain—4 percent. Thirty-nine percent was shipped to regions within the northern group.

Southern. —Southern manufacturers produced 15 percent (4,097,800 bd. ft.) of the total maple flooring shipments (fig. 3, tables 1 and 3). Of this amount, wholesalers distributed 65 percent; agents and brokers, 17 percent; flooring subcontractors, 8 percent; retailers, 5 percent; nonstocking wholesalers, 4 percent; and builders, 1 percent. About 25 percent of the flooring from the southern producers was shipped to the Middle Atlantic Region, 65 percent to regions within the southern group, 4 percent to the New England Region, and 3 percent to each of the Pacific and East North

Central Regions. No flooring was shipped into the West South Central and Mountain Regions by southern producers.

Channels of Distribution

Channels of distribution may be categorized into two groups—the distributor group and the intermediaries. The distributor group is comprised of builders, flooring subcontractors, retailers, and wholesalers who buy the flooring from the manufacturer and take title to it. The intermediaries group is comprised of nonstocking wholesalers and agents and brokers who act as marketing intermediaries and do not take title to the flooring.

Maple flooring manufacturers sold about 94 percent of the maple strip flooring directly to distributors; and about 6 percent was sold through intermediaries (fig. 3, tables 5 through 12).

Flooring subcontractors.—The flooring subcontractors handled about 66 percent (17,953,700 bd. ft.) of the total maple strip flooring shipments (fig. 2, tables 5 and 6); and about 98 percent of this was shipped from northern producers. About 22 percent was distributed to the East North Central Region, 15 percent to the South Atlantic Region, 14 percent to each of the West North Central and Middle Atlantic Regions, 11 percent to the West South Central Region, 7 percent to the New England Region, 6 percent to each of the East South Central and Pacific Regions, and 5 percent to the Mountain Region.

Wholesalers.—Wholesalers handled 23.6 percent (6,529,500 bd. ft.) of the total maple strip flooring (fig. 3, tables 5 and 7). Of this, about 61 percent was manufactured by northern producers, and 39 percent was manufactured by southern producers. Wholesalers distributed about 42 percent to the South Atlantic Region, 24 percent to the Middle Atlantic Region, 10 percent to the Pacific Region, 10 percent to the East North Central Region, 6 percent to the East South Central Region, 4 percent to the West North Central Region, 3 percent to the New England Region, and

0.6 percent to the West South Central Region. No flooring was distributed by wholesalers to the Mountain Region.

Nonstocking wholesalers.—Nonstocking wholesalers handled 3.3 percent (906,300 bd. ft.) of the total maple strip flooring (fig. 3, tables 5 and 8). About 81 percent of this was shipped by northern producers, and 19 percent was shipped by southern producers. Nonstocking wholesalers distributed about 43 percent to the Middle Atlantic Region, 37 percent to the South Atlantic Region, 13 percent to the East South Central Region, 4 percent to the Pacific Region, 3 percent to the New England Region, and 1/10th percent to the East North Central Region. None was distributed to the West North Central, West South Central, and Mountain Regions.

Agents and brokers.—Agents and brokers handled 3 percent (858,200 bd. ft.) of the total maple strip flooring (fig. 3, tables 5 and 11). About 22 percent of this was produced by northern producers, and 78 percent was produced by southern producers. Agents and brokers distributed about 60 percent to the Middle Atlantic Region, 34 percent to the South Atlantic Region, 5 percent to the New England Region, and 1 percent to the East North Central Region. No flooring was distributed to the West North Central, East South Central, West South Central, Mountain, and Pacific Regions.

Builders.—Builders handled 2.0 percent (554,900 bd. ft.) of the total maple strip flooring (fig. 3, tables 5 and 10). About 91 percent of this was shipped by northern producers, and 9 percent was shipped by southern producers. Builders distributed about 94 percent to the Middle Atlantic Region, 4 percent to the East South Central Region, and 1 percent to each of the East North Central and South Atlantic Regions. No flooring was distributed to the New England, West North Central, West South Central, Mountain, and Pacific Regions.

Retailers.—Retailers handled 1.7 percent (466,900 bd. ft.) of the total maple strip flooring in 1969 (fig. 3, tables 5 and 11). About 61 percent of this was produced by northern pro-

ducers and 39 percent was produced by southern producers. Retailers distributed about 26 percent to the East North Central Region, 20 percent to the West North Central Region, 15 percent to each of the Middle Atlantic and East South Central Regions, 10 percent to the South Atlantic Region, 9 percent to the New England Region, and 6 percent to the West South Central Region. No retailers sold flooring in the Mountain and Pacific Regions.

Destination of Shipments

About 71 percent of the total maple strip flooring was shipped to the regions east of the Mississippi River (fig. 3, tables 13 and 14). About 22 percent (6,139,100 bd. ft.) of this was shipped to the South Atlantic Region, 20 percent to the Middle Atlantic Region, 17 percent to the East North Central, 10 percent to the West North Central, 8 percent to the West South Central Region, 7 percent to the Pacific Region, 6 percent to each of the East South Central and New England Regions, and 4 percent to the Mountain Region.

New England.—About 5.8 percent (1,578,500 bd. ft.) of the total shipments of maple strip flooring went to the New England Region (fig. 3, tables 13 and 14). About 89 percent of this was manufactured by northern producers, and 11 percent was manufactured by southern producers. Flooring subcontractors distributed about 79 percent; wholesalers distributed 14 percent; retailers distributed 3 percent; and nonstocking wholesalers and agents and brokers each distributed about 2 percent. No flooring was distributed by builders.

Middle Atlantic.—Shipments of maple strip flooring into the Middle Atlantic Region represented about 20 percent (5,539,200 bd. ft.) of the total United States shipments (fig. 3, tables 13 and 14). Northern manufacturers produced 82 percent of this, and southern manufacturers produced 18 percent. Flooring subcontractors distributed about 46 percent; wholesalers, 27 percent; builders, 9 percent; agents

and brokers, 9 percent; nonstocking wholesalers, 7 percent; and retailers, 1 percent.

East North Central.—About 17 percent (4,647,400 bd. ft.) of the total maple strip flooring was shipped into the East North Central Region (fig. 3, tables 13 and 14); and 98 percent of it came from northern producers. Flooring subcontractors distributed about 84 percent; wholesalers, 13 percent; retailers, 2 percent; and builders, nonstocking wholesalers, and agents and brokers, each less than ½ percent.

West North Central.—About 10 percent (2,822,900 bd. ft.) of the total maple flooring shipments went to the West North Central Region (fig. 3, tables 13 and 14); and almost all of the shipments came from northern manufacturers. About 87 percent was distributed by flooring subcontractors, 10 percent by wholesalers, and 3 percent by retailers. No flooring was handled by builders, nonstocking wholesalers, and agents and brokers.

South Atlantic.—The South Atlantic Region was the destination for about 22.5 percent (6,139,100 bd. ft.) of the total shipments of maple flooring (fig. 3, tables 13 and 14). Sixty-two percent was shipped by northern producers and 38 percent was shipped by southern producers. Flooring subcontractors and wholesalers each handled about 45 percent; nonstocking wholesalers and agents and brokers each distributed 5 percent; and builders and retailers each distributed less than 1 percent.

East South Central.—Shipments of maple strip flooring into the East South Central Region accounted for about 6 percent (1,646,400 bd. ft.) of the total shipments (fig. 3, tables 13 and 14). About 79 percent originated at northern mills, and 21 percent originated at southern mills. Flooring subcontractors distributed about 64 percent; wholesalers, 23 percent; nonstocking wholesalers, 7 percent; retailers, 5 percent; and builders, 1 percent. No flooring was distributed by agents and brokers.

West South Central.—About 8 percent (2,110,300 bd. ft.) of the total maple strip flooring shipments went to the West South Central Region (fig. 3, tables 13 and 14); and northern manufacturers produced all of it. Flooring subcontractors distributed about 98 percent; and retailers and wholesalers each handled 1 percent. None was distributed by builders, nonstocking wholesalers, and agents and brokers.

Mountain.—About 4 percent (974,600 bd. ft.) of the total maple strip flooring shipments went to the Mountain Region (fig. 3, tables 13 and 14); and all of it came from northern manufacturers. Flooring subcontractors distributed all of the flooring shipments to the Mountain Region.

Pacific.—Shipments of maple strip flooring into the Pacific Region accounted for about 7 percent (1,811,100 bd. ft.) of the total shipments (fig. 3, tables 13 and 14). Northern mills produced about 92 percent and southern mills produced about 8 percent. About 60 percent was distributed by flooring subcontractors, 38 percent by wholesalers, and 2 percent by nonstocking wholesalers. Builders, retailers and agents and brokers did not distribute any flooring to the region.

Total United States.—Northern and southern manufacturers shipped about 85 percent and 15 percent, respectively, of the total United States shipments of 27,269,500 bd. ft. of maple strip flooring (fig. 3, tables 13 and 14). Flooring subcontractors distributed about 66 percent; wholesalers handled 24 percent; nonstocking wholesalers and agents and brokers each distributed 3 percent; and builders and retailers each distributed 2 percent.

PROMOTIONAL PRACTICES

Four questions pertaining to advertising were asked of the manufacturers. First, what media were used? Note that responding manufacturers may have used more than one advertising medium during 1969. Of the five northern manufacturers who responded, four advertised in trade papers, magazines, and journals; three advertised through brochures and pamphlets; three advertised in other media such

as Sweet's catalog, trade shows, and displays; two advertised in trade directories; one advertised in consumer magazines; and one did not advertise. Regular newspapers and telephone books were not used by any of the responding northern producers.

Of the nine southern producers, five advertised in trade papers, magazines, and journals; five had advertisements in the telephone books; four used other advertising media such as trade and home shows and direct mailing; three advertised in trade directories; three advertised through brochures and pamphlets; two advertised in consumer magazines; two advertised in regular newspapers; and three did not advertise.

The second question was: Which media were most effective? Of the four northern producers responding, two considered Sweet's catalog to be the most effective because of its wide use by architects; one considered brochures and pamphlets most effective; one considered trade papers, magazines, and journals most effective.

The third question was: Which media were least effective? Two of the three northern manufacturers responding considered regular newspapers to be least effective because of the lack of a local market; and one considered trade directories least effective.

The fourth question was: How many advertised cooperatively with distributors? Two of the five northern producers and three of the nine southern producers advertised cooperatively with distributors.

Distributional Changes

Three questions pertaining to past and expected changes in distribution were asked of manufacturers. First, has the geographic distribution of shipments changed since 1960? Three of five northern producers reported moderate changes in the geographic distribution of their shipments and two reported that shipments had remained about the same. The

moderate changes indicated by northern producers were mainly increases in shipments to regions east of the Mississippi River and decreases to regions west of the Mississippi River. Five of eight southern producers reported shipments had remained about the same; two indicated moderate changes; and one reported considerable changes. The changes reported by southern producers were decreases to regions east of the Mississippi River and increases to regions west of the Mississippi River.

The second question was: Have the channels of distribution changed since 1960? Three of the five northern producers indicated that the distribution channels had remained about the same; one reported moderate change; and one reported considerable change. The changes indicated by northern producers were more direct sales to flooring subcontractors, retail chains, and wholesalers who acted in the role of flooring subcontractors by employing professional flooring installation personnel. Six of nine southern producers reported that the distribution channels had remained about the same; and three indicated moderate changes. The changes indicated by southern manufacturers were more direct sales to specialty flooring distributors, mobile home manufacturers, and larger builders.

The third question was: Compared to 1969, what changes in the distribution system are expected by 1975? Three of five northern producers expect moderate changes by 1975; and two expect the system to remain the same. Changes expected are that flooring companies will be required to start floor laying subsidiaries, and that more direct sales will be made to flooring subcontractors and retail yards. Four of the eight southern producers expect the system to remain the same; three expect moderate changes; and one expects considerable changes. Changes expected by southern producers are more direct sales to flooring subcontractors, mobile home builders, and modular or component type home builders.

Discussion and Summary

Maple strip flooring production is concentrated in the Northern Lake States area, primarily in the States of Michigan and Wisconsin. Eighty-five percent of the shipments of maple strip flooring came from this area. The other 15 percent was produced by manufacturers located in the Southern and Appalachian hardwood areas.

Total shipments varied from region to region throughout the United States. Over 71 percent of the total shipments of maple strip flooring went to regions east of the Mississippi River. The South Atlantic, Middle Atlantic, and East North Central Regions ranked first, second, and third, respectively, in total maple flooring shipments. Conversely, the Mountain Region received the smallest volume of total shipments.

Flooring subcontractors and wholesalers were the first and second most important type of distributors of maple strip flooring shipments. Flooring subcontractors handled about 66 percent of the United States maple strip flooring shipments; and wholesalers handled about 24 percent of the total shipments.

The two geographic production groups—northern and southern—used different channels of distribution. These differences are linked directly to the channels of distribution used by each geographic manufacturing group for the movement of their primary product. Seventy-six percent of the maple flooring shipped by northern manufacturers was sold directly to flooring subcontractors; whereas only 8 percent of the southern manufacturers' shipments went directly to flooring subcontractors. On the other hand, 65 percent of the southern producers' flooring was sold directly to wholesalers, whereas only about 17 percent from the northern producers went directly to wholesalers.

Questions posed to manufacturers regarding advertising gave some insight into the promotional practices in the maple flooring industry. Both northern and southern producers reported that trade papers, trade magazines, and trade

journals were the primary media used to advertise maple strip flooring. Northern producers indicated that brochures and pamphlets, and other media such as Sweet's catalog were the second most frequently used advertising media. Southern producers reported telephone books as the second most frequently used advertising media. The primary end use of maple strip flooring is in educational facilities, consequently the advertising effort made by maple flooring manufacturers is not aimed at the residential consumer, but at the institutional consumer.

Northern producers considered advertising media such as Sweet's catalog to be the most effective and regular newspaper to be the least effective.

Very little cooperative advertising with distributors was indicated by either northern or southern maple flooring manufacturers.

Most northern producers of maple flooring reported that the geographic distribution of shipments had changed moderately since 1960; whereas most southern producers indicated that geographic shipment distributions has remained about the same. Northern producers noted increases in shipments to regions in the eastern half of the United States and decreases in shipments to regions in the western half of the country.

Most northern and southern producers indicated there had been very few changes in the channels of distribution since 1960.

Most northern producers of maple strip flooring expect moderate changes in the distribution system by 1975; whereas most southern producers expect the system to remain the same. Northern producers expect that flooring companies will be required to start floor laying subsidiaries and that more direct sales will be made to flooring subcontractors and retail yards.

Tabular Data

Table 1.—1969 production of maple strip flooring by geographic division

Geographic division	Production total (MBF)	Percent of U.S. total
Northern	23,171.7	85.0
Southern	4,097.8	15.0
U.S. TOTAL	27,269.5	100.0

Table 2. Distribution of maple strip flooring from the northern production division, 1969 (in percent)

[Division production total, 23,171.7 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Distributors							Percent of—	
	Builders	Flooring sub-contractors	Retailers	Whole-salers	Non-stocking whole-salers	Agents and brokers	Total	Division total production	U.S. total
New England	0	87.7	0	11.0	1.3	0	100.0	6.0	5.1
Middle Atlantic	11.1	55.8	0	22.1	7.0	4.0	100.0	19.5	16.6
East North Central	0	85.5	2.3	12.2	0	0	100.0	19.7	16.7
West North Central	0	87.2	2.9	9.9	0	0	100.0	12.2	10.4
South Atlantic	0	62.9	.6	30.0	6.5	0	100.0	16.5	14.0
East South Central	0	77.9	3.2	11.2	7.7	0	100.0	5.6	4.8
West South Central	0	97.5	1.2	1.3	0	0	100.0	9.1	7.7
Mountain	0	100.0	0	0	0	0	100.0	4.2	3.6
Pacific	0	64.3	0	33.5	2.2	0	100.0	7.2	6.1
Whole U.S.	2.2	76.0	1.2	16.7	3.1	.8	100.0	100.0	85.0

Table 3.—Distribution of maple strip flooring from the southern production division, 1969 (in percent)

[Division production total, 4,097.8 MBF. U.S. total, 27,269.5 MBF.]

Shipment destination by geographic region	Distributors							Percent of—	
	Builders	Flooring sub-contractors	Retailers	Whole-salers	Non-stocking whole-salers	Agents and brokers	Total	Division total production	U.S. total
New England	0	0	25.8	42.0	6.4	25.8	100.0	4.0	0.7
Middle Atlantic	1.7	0	7.2	52.2	6.5	32.4	100.0	25.3	3.7
East North Central	5.6	0	12.3	71.5	1.1	9.5	100.0	2.7	.4
West North Central	0	0	100.0	0	0	0	100.0	.3	(1)
South Atlantic	.3	13.9	1.0	68.8	3.6	12.4	100.0	56.5	8.5
East South Central	8.1	4.0	9.1	73.2	5.6	0	100.0	8.0	1.2
West South Central	0	0	0	0	0	0	0	0	0
Mountain	0	0	0	0	0	0	0	0	0
Pacific	0	0	0	100.0	0	0	100.0	3.3	.5
Whole U.S.	1.3	8.3	4.6	64.8	4.4	16.6	100.0	100.0	15.0

[1] Less than 0.05.

Table 4.—Distribution of maple strip flooring from all production divisions, 1969 (in percent)

[Total production, 27,269.5 MBF.]

Shipment destination by geographic region	Distributors							Percent of U.S. total
	Builders	Flooring sub-contractors	Retailers	Whole-salers	Non-stocking whole-salers	Agents and brokers	Total	
New England	0	78.9	2.6	14.1	1.9	2.5	100.0	5.8
Middle Atlantic	9.4	46.0	1.3	27.4	6.9	9.0	100.0	20.3
East North Central	.1	83.7	2.5	13.5	([1])	.2	100.0	17.1
West North Central	0	87.0	3.2	9.8	0	0	100.0	10.4
South Atlantic	.1	45.0	.7	44.2	5.5	4.5	100.0	22.5
East South Central	1.5	64.2	4.3	22.7	7.3	0	100.0	6.0
West South Central	0	97.5	1.2	1.3	0	0	100.0	7.7
Mountain	0	100.0	0	0	0	0	100.0	3.6
Pacific	0	59.8	0	38.1	2.1	0	100.0	6.6
Whole U.S.	2.0	66.4	1.7	23.6	3.3	3.0	100.0	100.0

[1] Less than 0.05.

Table 5.—Volume of maple strip flooring production handled by major distributors

Distributor	Production total (MBF)	Percent of U.S. total
Builders	554.9	2.0
Flooring subcontractors	17,953.7	66.4
Retailers	466.9	1.7
Wholesalers	6,529.5	23.6
Nonstocking wholesalers	906.3	3.3
Agents and brokers	858.2	3.0
U.S. TOTAL	27,269.5	100.0

Table 6.—Flooring subcontractors' distribution of maple strip flooring, 1969 (in percent)

[Total distribution, 17,953.7 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	100.0	0	100.0	6.9	4.6
Middle Atlantic	100.0	0	100.0	14.0	9.3
East North Central	100.0	0	100.0	21.7	14.4
West North Central	100.0	0	100.0	13.7	9.1
South Atlantic	88.7	11.3	100.0	15.2	10.1
East South Central	98.8	1.2	100.0	5.7	3.8
West South Central	100.0	0	100.0	11.4	7.5
Mountain	100.0	0	100.0	5.4	3.6
Pacific	100.0	0	100.0	6.0	4.0
Whole U.S.	98.2	1.8	100.0	100.0	66.4

Table 7.—Wholesalers' distribution of maple strip flooring, 1969 (in percent)

[Total distribution, 6,529.5 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	70.4	29.6	100.0	3.5	0.8
Middle Atlantic	66.5	33.5	100.0	23.6	5.6
East North Central	89.2	10.8	100.0	9.8	2.3
West North Central	100.0	0	100.0	4.4	1.0
South Atlantic	43.0	57.0	100.0	41.9	10.0
East South Central	40.2	59.8	100.0	6.0	1.4
West South Central	100.0	0	100.0	.6	.1
Mountain	0	0	0	0	0
Pacific	81.6	18.4	100.0	10.2	2.4
Whole U.S.	60.7	39.3	100.0	100.0	23.6

Table 8.—Nonstocking wholesalers' distribution of maple strip flooring, 1969 (in percent)

[Distribution total, 906.3 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	64.5	35.5	100.0	3.1	0.1
Middle Atlantic	83.6	17.4	100.0	42.7	1.4
East North Central	0	100.0	100.0	.1	([1])
West North Central	0	0	0	0	0
South Atlantic	75.8	24.2	100.0	36.9	1.2
East South Central	85.9	14.1	100.0	13.0	.4
West South Central	0	0	0	0	0
Mountain	0	0	0	0	0
Pacific	100.0	0	100.0	4.2	.2
Whole U.S.	81.0	19.0	100.0	100.0	3.3

[1] Less than 0.05.

Table 9.—Agents' and brokers' distribution of maple strip flooring, 1969 (in percent)

[Distribution total, 858.2 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	0	100.0	100.0	4.9	0.2
Middle Atlantic	36.4	63.6	100.0	60.4	1.8
East North Central	0	100.0	100.0	1.1	([1])
West North Central	0	0	0	0	0
South Atlantic	0	100.0	100.0	33.6	1.0
East South Central	0	0	0	0	0
West South Central	0	0	0	0	0
Mountain	0	0	0	0	0
Pacific	0	0	0	0	0
Whole U.S.	22.0	78.0	100.0	100.0	3.0

[1] Less than 0.05.

Table 10.—Builders' distribution of maple strip flooring, 1969 (in percent)

[Distribution total, 554.9 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	0	0	0	0	0
Middle Atlantic	96.7	3.3	100.0	93.7	1.9
East North Central	0	100.0	100.0	1.0	([1])
West North Central	0	0	0	0	0
South Atlantic	0	100.0	100.0	1.0	([1])
East South Central	0	100.0	100.0	4.3	.1
West South Central	0	0	0	0	0
Mountain	0	0	0	0	0
Pacific	0	0	0	0	0
Whole U.S.	90.7	9.3	100.0	100.0	2.0

[1] Less than 0.05.

Table 11.—Retailers' distribution of maple strip flooring, 1969 (in percent)

[Distribution total, 466.9 MBF. U.S. total, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of—	
	Northern	Southern	Total	Distribution total	U.S. total
New England	0	100.0	100.0	8.8	0.1
Middle Atlantic	0	100.0	100.0	15.3	.3
East North Central	90.1	9.9	100.0	25.8	.4
West North Central	91.8	8.2	100.0	19.8	.3
South Atlantic	49.3	50.7	100.0	9.6	.2
East South Central	60.7	39.3	100.0	15.0	.3
West South Central	100.0	0	100.0	5.7	.1
Mountain	0	0	0	0	0
Pacific	0	0	0	0	0
Whole U.S.	61.0	39.0	100.0	100.0	1.7

Table 12.—All distributors' distribution of maple strip flooring, 1969 (in percent)

[Total distribution, 27,269.5 MBF]

Shipment destination by geographic region	Production by geographic division			Percent of U.S. total
	Northern	Southern	Total	
New England	92.4	7.6	100.0	5.8
Middle Atlantic	80.6	19.4	100.0	20.3
East North Central	98.0	2.0	100.0	17.1
West North Central	99.7	.3	100.0	10.4
South Atlantic	63.4	36.6	100.0	22.5
East South Central	81.5	18.5	100.0	6.0
West South Central	100.0	0	100.0	7.7
Mountain	100.0	0	100.0	3.6
Pacific	93.0	7.0	100.0	6.6
Whole U.S.	85.0	15.0	100.0	100.0

Table 13.—Destination of shipments of maple strip flooring, 1969

Geographic region	Shipment total (MBF)	Percent of U.S. total
New England	1,578.5	5.8
Middle Atlantic	5,539.2	20.3
East North Central	4,647.4	17.1
West North Central	2,822.9	10.4
South Atlantic	6,139.1	22.5
East South Central	1,646.4	6.0
West South Central	2,110.3	7.7
Mountain	974.6	3.6
Pacific	1,811.1	6.6
U.S. TOTAL	27,269.5	100.0

Table 14.—Distribution of maple strip flooring—all regions, 1969
(in percent)
[Total U.S. production, 27,269.5 MBF]

Shipment destination by geographic region	Production from geographic division	Distributors						Total	Percent of—	
		Builders	Flooring sub-contractors	Retailers	Wholesalers	Non-stocking wholesalers	Agents and brokers		Regional total	U.S. total
New England	Northern	0	87.7	0	11.0	1.3	0	100.0	88.8	5.1
(1,578.5 MBF)[1]	Southern	0	0	25.8	42.0	6.4	25.8	100.0	11.2	.7
	Both divisions	0	78.9	2.6	14.1	1.9	2.5	100.0	100.0	5.8
Middle Atlantic	Northern	11.1	55.8	0	22.1	7.0	4.0	100.0	81.6	16.6
(5,539.2 MBF)	Southern	1.7	0	7.2	52.2	6.5	32.4	100.0	18.4	3.7
	Both divisions	9.4	46.0	1.3	27.4	6.9	9.0	100.0	100.0	20.3
East North Central	Northern	0	85.5	2.3	12.2	0	0	100.0	97.8	16.7
(4,647.4 MBF)	Southern	5.6	0	12.3	71.5	1.1	9.5	100.0	2.2	.4
	Both divisions	.1	83.7	2.5	13.5	(2)	.2	100.0	100.0	17.1
West North Central	Northern	0	87.2	2.9	9.9	0	0	100.0	99.7	10.4
(2,822.9 MBF)	Southern	0	0	100.0	0	0	0	100.0	.3	(2)
	Both divisions	0	87.0	3.2	9.8	0	0	100.0	100.0	10.4
South Atlantic	Northern	0	62.9	.6	30.0	6.5	0	100.0	62.3	14.0
(6,139.1 MBF)	Southern	.3	13.9	1.0	68.8	3.6	12.4	100.0	37.7	8.5
	Both divisions	.1	45.0	.7	44.2	5.5	4.5	100.0	100.0	22.5
East South Central	Northern	0	77.9	3.2	11.2	7.7	0	100.0	78.8	4.8
(1,646.4 MBF)	Southern	8.1	4.0	9.1	73.2	5.6	0	100.0	21.2	1.2
	Both divisions	1.5	64.2	4.3	22.7	7.3	0	100.0	100.0	6.0
West South Central	Northern	0	97.5	1.2	1.3	0	0	100.0	100.0	7.7
(2,110.3 MBF)	Southern	0	0	0	0	0	0	0	0	0
	Both divisions	0	97.5	1.2	1.3	0	0	100.0	100.0	7.7
Mountain	Northern	0	100.0	0	0	0	0	100.0	100.0	3.6
(974.6 MBF)	Southern	0	0	0	0	0	0	0	0	0
	Both divisions	0	100.0	0	0	0	0	100.0	100.0	3.6
Pacific	Northern	0	64.3	0	33.5	2.2	0	100.0	91.9	6.1
(1,811.1 MBF)	Southern	0	0	0	100.0	0	0	100.0	8.1	.5
	Both divisions	0	59.8	0	38.1	2.1	0	100.0	100.0	6.6
U.S. total	Northern	2.2	76.0	1.2	16.7	3.1	.8	100.0	——	85.0
(27,269.5 MBF)	Southern	1.3	8.3	4.6	64.8	4.4	16.6	100.0	——	15.0
	Both divisions	2.0	66.4	1.7	23.6	3.3	3.0	100.0	——	100.0

[1] Total shipped to the region.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

by James S. Jordan

Dispersal period in a population of EASTERN FOX SQUIRRELS (*Sciurus niger*)

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The study reported here was done when the author was a research biologist in the Illinois Natural History Survey, Urbana, Illinois.

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TIMING OF THE annual dispersal movement in fox squirrels has important implications in the management of the species, especially in setting harvest regulations. Estimates of squirrel populations are frequently used in setting these regulations. But these estimates may be biased if the dispersal movement is concurrent with the collection of data from which the estimates are made.

The dispersal period in fox squirrels has not been clearly established. It has been reported to occur between 10 August and 15 September in Ohio *(Baumgartner 1943)*, from late August to the middle of December in Michigan *(Allen 1943)*, and during the fall in Illinois *(Brown and Yeager, 1945)*. Though not specifically designed to determine the dispersal period of fox squirrels, these studies have nevertheless been a major source of information on the subject.

This is a report on the results of a more recent study of a fox squirrel population that does pertain to the dispersal movement.

STUDY AREA AND METHODS

The study was conducted in 1954 in a 68-acre oak-hickory woods located near Havana in west-central Illinois. The privately owned woods, roughly rectangular in shape, was bounded on three sides by fields and a fenced pasture, and on the fourth and shortest side by a public road. Opposite this road was another oak-hickory woods and a young pine plantation. More than one-third of the study area was occupied by a stand of old-growth timber; the rest of the area was stocked with a mixture of pole- and sawtimber-size trees. The woods was posted against trespass during the study and was identified as a research study area. It had not been posted previously.

Live-trapping operations were conducted on the study area from 14 January to 21 May and, except for September, from 27 July to 11 November. Average trap density during the study varied from a minimum of one trap per 2 acres to a maximum of one trap per 0.7 acre.

Trapping was carried out on 39 days during the first period (2,415 trap-days) and on 35 days during the second period (2,117 trap-days). Traps were placed in irregular lines across the study area in locations thought most likely to be successful in taking squirrels; their locations were changed often thereafter to increase trap success. The traps used were a modified version of that described by Baumgartner *(1940)*. Bait consisted mainly of papershell pecans; hickory nuts (Carya spp.) and shelled corn were also used.

Captured squirrels were ear-tagged with serially numbered tags. The tags also carried the local telephone number of the Illinois Natural History Survey for use by hunters who bagged tagged squirrels outside the study area. Squirrels were also toe-clipped according to a standard formula for permanent identification.

The sex, age, weight, and condition of squirrels were recorded at the site of capture. Three age classes were used for all squirrels captured from January to May: adult, subadult (summer born, 1953), and juvenile (spring born, 1954). Criteria used in age determination closely followed those described by Brown and Yeager *(1943)* and Shorten *(1951)*. To distinguish between adult and subadult males, observations were made of the color of the scrotum and the extent to which it was covered with hair; the color of the skin on the soles of the feet (gray or black); the relative size of the scrotum, testes, and Cowper's glands; and the weight of the animal. When used collectively, these criteria were thought to be effective even in difficult cases. Age determination in females presented no difficulty.

Squirrels initially captured from July to November were determined to be adults or juveniles (spring-born, 1954). The age characters described above for males were also used to distinguish between adult and juvenile males during the fall season. Obser-

vations of the development of three spring-born males, captured in another area and held in large wire-enclosed pens from April to mid-November, aided in the age determination. Squirrels born in the summer of 1954 were easily distinguished from older squirrels; however, information on summer-born squirrels was not used in determining the dispersal period.

All hunting of squirrels on the study area was done by personnel of the Illinois Natural History Survey during the 61-day open season, 1 September to 31 October *(Jordan 1971)*.

RESULTS AND DISCUSSION

From 14 January to 21 May, 126 fox squirrels were captured. Five died in the traps and 121 were presumed to be available for recapture or hunting during the period 27 July to 11 November. Sixty-two (51 percent) of these squirrels were recaptured or bagged during the latter period.

The rate of return of marked squirrels varied among sex and age classes (table 1). It was higher for males than for females, and progressively higher for older squirrels. Within the three age classes (adult, subadult, and juvenile), the rate of return of males greater among both adult and juvenile squirrels, and about the same as that of females among subadults. Among juveniles, the rate of return of males was 2.8 times that of females. The greatest contrast among all rates of return was that between adult males (74 percent) and juvenile females (22 percent).

Yet tests of chi-square values of 7.42, 5.35, and 4.43 strongly suggested acceptance of the hypothesis that there were no significant differences ($P < .05$) between the numbers of squirrels returned and the numbers expected among, respectively, the six sex-age classes, three age classes of females, and three age classes of males. However, acceptance of this hypothesis would imply that if a dispersal movement, or natural mortality, had occurred within the population on the study area, these events were distributed proportionately among all sex and age classes. The general consistency among the rates of return that favored both males and older squirrels does not support this conclusion.

Table 1.—*Rates of return, by age-sex classes, of fox squirrels marked 15 January to 21 May and recaptured or bagged 27 July to 11 November, 1954*

Item	Adult			Subadult			Juvenile			All age classes		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Number marked	19	34	53	16	7	23	18	27	45	53	68	121
Number returned	14	21	35	7	3	10	11	6	17	32	30	62
Percent returned	74	62	66	44	43	44	61	22	38	58	44	51

The observed rates of return of marked squirrels suggest instead that there was a dispersal movement, that the dispersal was greatest among juvenile squirrels, somewhat less among subadults, and least among adults; and that it also contained a proportionately greater number of females. Also, that while natural mortality within the population undoubtedly occurred, especially among juvenile squirrels involved in the dispersal movement, any differential rate of natural mortality among the sex and age classes probably was largely the result of the hazards of dispersal and was masked by the main effect of dispersal.

If natural mortality had been the main cause of the difference among the rates of return, then natural mortality among juveniles was highly selective against females, but nonselective between juvenile males and adult females, and more selective against subadults than against juvenile males. This seems unlikely. Juvenile males and females appeared to be at similar stages of physical development when initially captured 16 April to 21 May. The average weight of the 45 juveniles was 340 grams or a little less than half the average weight of 735 grams for 26 adult squirrels captured 24 March to 21 May. There was virutally no difference between the average weights of male and female juveniles (345 and 331 grams, respectively) at initial capture. Natural mortality that may have occurred among juveniles before 16 April is, of course, excluded from this discussion.

Five squirrels captured before 22 May were reported bagged outside the study area. One of these was a subadult male, one was a juvenile male, and three were juvenile females. The juvenile male had been recaptured 19 August on the study area.

These results suggest that the main dispersal movement occurred before August, though they do not rule out the possibility that it occurred later. Other results support the view that the movement actually occurred before 1 August.

Of the 121 squirrels captured before 22 May, only 23 were recaptured between 27 July and 25 August. Sixteen (70 percent) of these 23 squirrels were later bagged or recaptured between 1 September and 11 November. Of 18 squirrels that were initially captured from 27 July to 25 August, 16 (89 percent) were

Table 2.—*Rates of return, by age-sex classes, of fox squirrels captured or recaptured 27 July to 25 August and bagged or again taken 1 September to 11 November, 1954*

Item	Adult			Juvenile			Adult and Juvenile		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Number marked	9	11	20	11	10	21	20	21	41
Number returned	6	11	17	8	7	15	14	18	32
Percent returned	67	100	85	73	70	71	70	86	78

Table 3.—*Proportion of marked fox squirrels among all squirrels bagged or recaptured, by age classes, for three periods between 1 September and 11 November, 1954.*

Item	Adult			Juvenile		
	Unmarked	Marked		Unmarked	Marked	
	No.	*No.*	*Percent*	*No.*	*No.*	*Percent*
Shot 1 Sept.-13 Sept.	8	24	75	45	14	24
Shot 16 Sept.-30 Sept.	1	3	75	13	5	28
Shot or trapped 1 Oct.-11 Nov.	9	13	59	34	12	26
Total	18	40	69	92	31	25

bagged or recaptured from 1 September to 11 November. The rate of return among the 41 squirrels livetrapped 27 July to 25 August was 78 percent (table 2).

The rates of return among the sex and age classes (table 2) generally exceeded those among the squirrels marked 14 January to 21 May. The high rate of return of juvenile squirrels, notably that of juvenile females (table 2), was in marked contrast to those of juvenile squirrels captured before 22 May (table 1).

If the two groups of marked squirrels were representative samples of the populations present at the time they were captured, the differences in rates of return indicate that the main dispersal movement occurred sometime between late May and late July.

There was a possibility that the returns among all marked squirrels during the period 1 September to 11 November was completed before the end of that period and that dispersal then occurred and went unnoticed. But the proportion of marked to unmarked squirrels bagged or recaptured did not indicate that this had happened (table 3). The proportion of marked juvenile squirrels bagged or recaptured was fairly constant for three periods between 1 September and 11 November. The proportion of marked adults declined in the last period. However, adult females may have been more vulnerable to the gun during the early part of the hunting season than were other sex and age classes *(Jordan 1971)*. This would tend to inflate the return of adults for the first two periods.

It was not determined whether there was a dispersal period among squirrels born during the summer of 1954. Thirteen were bagged in September and October and 24 others were captured in October and November.

The estimated populations at the beginning and end of the hunting season were 240 and 96 squirrels, respectively *(Jordan (1971)*.

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by Clayton M. Carl, Jr.
and Albert G. Snow, Jr.

MATURATION of SUGAR MAPLE SEED

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ALBERT G. SNOW, JR., received his bachelor of science degree in forestry from Washington State College in 1933, and his master of science degree from Yale Unisity in 1935. He joined the Northeastern Forest Experiment Station in 1935 and worked as a research forester in spruce management and forest genetics. He transferred to the Southeastern Forest Experiment Station, Lake City, Florida, in 1942 as a research forester in naval stores. He was center leader at the Virginia Pine-Hardwood Research Center, Laurel, Maryland, from 1952-61. He served as project leader and chief of laboratory of the Station's unit in Burlington, Vermont, from 1961 until he retired in May 1971.

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THE SEEDS of a sugar maple tree (*Acer saccharum* Marsh.) do not mature at the same time every year. And different trees mature their seeds at different times. So time of year is not a reliable measure of when seeds are ripe. Better criteria are needed.

In recent studies we have found that moisture content and color are the best criteria for judging when sugar maple seeds are ripe.

Tree Selection

We collected sugar maple samaras from three trees growing in an open stand of sugar maples about 9 miles southeast of Burlington, Vermont. The trees were selected for percentage of filled samaras (50 percent or more contained seeds in 1964) and the proximity of the trees to each other. All three trees were mature, about the same height and diameter, and had full and fairly open-grown crowns. Because of the nearness of the trees to each other, we assumed that site and climatic conditions were uniform.

Samara Collection

The samaras were collected by hand-picking those that could be reached from the ground, and by pruning the tips of the higher samara-bearing branches. For each collection we tried to obtain samaras from all portions of the crown we could reach. The weekly collections were discontinued when not enough samaras could be gathered for the regular viability tests.

We started collecting samaras on 26 August 1964 from all three trees. Because the time of samara-fall varied between trees, the final collections were made on 7 October for tree A, on 21 October for tree B, and on 30 September for tree C—a total of 22 individual collections. The weekly collections consisted of approximately 1,100 samaras from each of three trees.

In 1967 samaras were collected from the same trees so that a comparison could be made between seed years. We started collecting on 30 August and continued collections weekly until the final collections were made on 12 October for trees A and C, and on 20 October for tree B—again a total of 22 individual collections. It was noted that tree C had a high aphid infestation on the fruits. With minor exceptions the samaras were handled the same as those collected in 1964.

Samara Handling

Moisture content determinations were made each week on five 100-samara samples from each tree. After removal from the tree, the samples were sealed immediately in glass jars. Upon return to the laboratory, the samples were weighed, dried at 100°C. for 24 hours, and reweighed. Percent moisture content at time of collection was calculated on a dry-weight basis.

Another five samples of 100 samaras each were used in the germination tests. They were slowly air-dried in an unheated building to a moisture content of about 10-15 percent. After drying they were stored at a temperature of 2°C. over winter until the germination tests were begun.

The remaining samaras from each collection were used for color determinations. The colors of the samaras and seed coats were compared to color plates in the Maerz and Paul *Dictionary of Color (1930).*

Germination Tests

The samaras were taken from storage the spring after collection and were soaked in tapwater for 24 hours at 2°C. They were then stratified for 90 days at 2°C., on germination paper in small plastic boxes *(Carl and Yawney 1966).* At the end of the 90 days they were transferred to a temperature of 15°C. for an additional 2 weeks. Weekly germination counts were begun, and germinated seeds were removed, after about the 30th day of stratification.

After the final germination counts were made, the remaining

samaras were opened to determine the number of ungerminated seeds present. This number plus the number of germinated seeds equaled the total number of seeds present in the original sample. Germination percentages were based on the total number of seeds present, not on the total number of samaras.

Time of Collection and Seed Germinability

In 1964, seeds could be collected any time after 1 September—for trees A and C—and they would be over 95 percent germinable (fig. 1). In tree B this state of seed maturation was not reached until the 23 September collection.

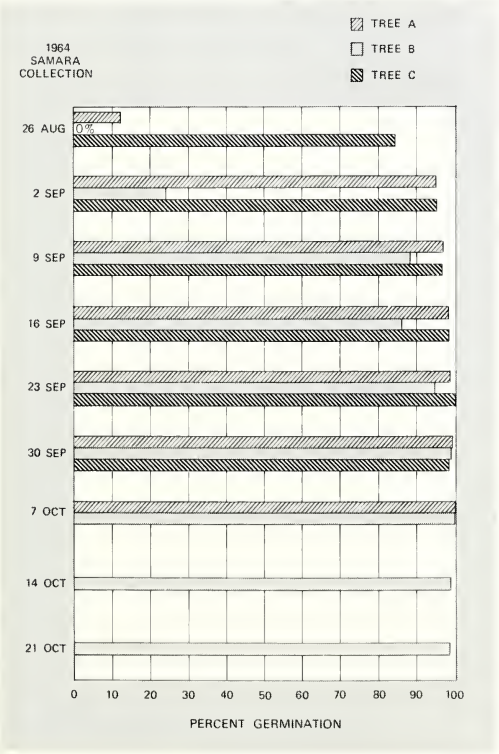


Figure 1.—Percent germination for each tree, by date of collection, 1964.

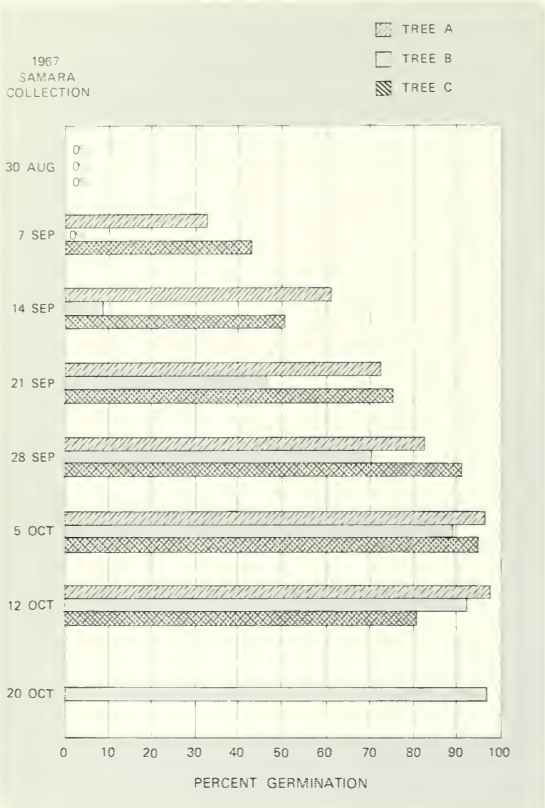


Figure 2.—Percent germination for each tree, by date of collection, 1967.

Seed matured at a much later date in 1967 (fig. 2). Not until about a month later — 5 October — were seed over 90 percent germinable. Again tree B lagged behind the other two in time of maximum seed maturation. The seasonal rate of seed maturation was also slower in 1967 than in 1964.

These results indicate two things. First, individual trees seem to have a built-in phenologic system that is repeatable from year to year for maturation of seed. Second, neither chronologic date of maximum seed germinability or rate of seed maturation are the same each year, thus ruling out both factors for predicting when samaras may be collected for best results.

There were only 2 weeks in 1964 when seeds from all three trees germinated at least 95 percent. Again in 1967, total germi-

nation varied between trees for the same date of collection and between dates of collection for each tree. No single week's collections had seeds from all three trees that germinated at the 95-percent level.

Moisture Content and Seed Germinability

There was a gradual decline in moisture content of the samaras for the 1964 season until about the last week of collection. Then there was a sharp drop in moisture content, and the samaras were shed. With minor exceptions, the 1967 pattern for change in the average moisture content was similar to that observed in 1964 (fig. 3). There was a general decline until about the last week, when again there was a sudden drop, and the samaras were shed.

Figure 3. — Moisture content of the weekly samara collections.

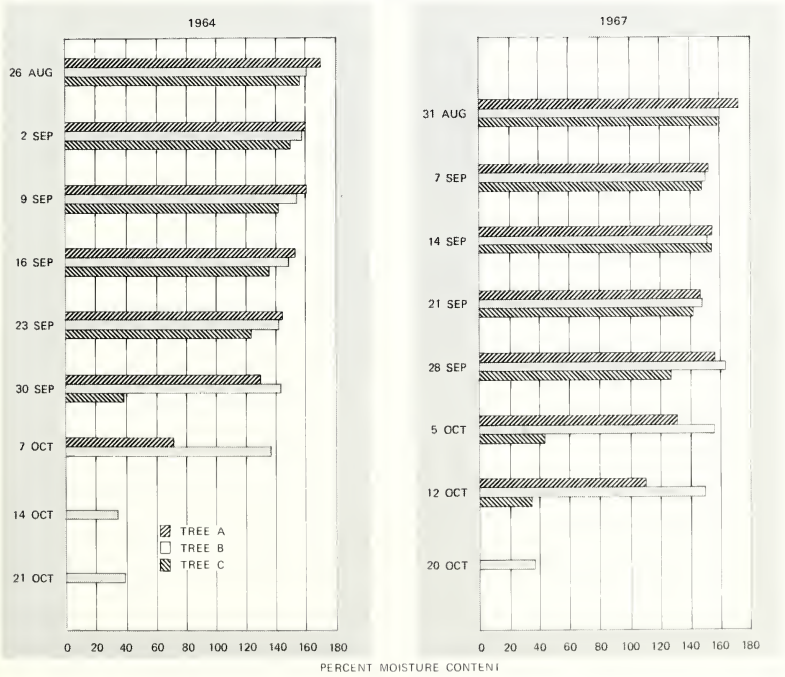
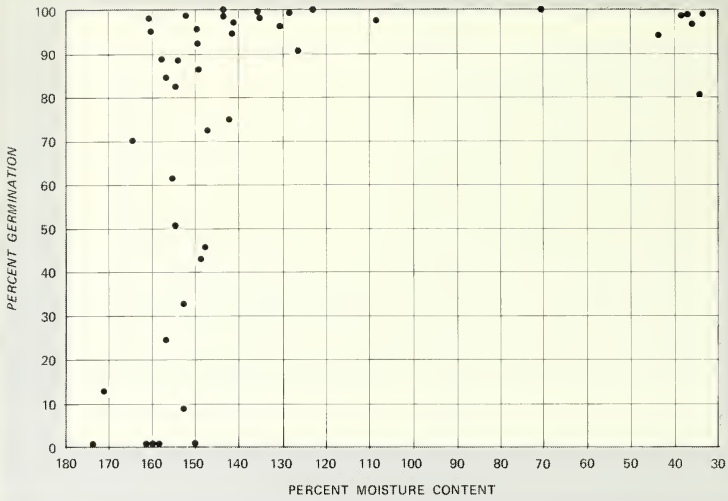


Figure 4.—The relationship between percent moisture content of the samaras at the time of collection and total percent seed germination.



When the moisture content was below 145 percent, nearly all the seed samples germinated at 95 percent or better (fig. 4). The exception to this was tree C, which had a high aphid infestation in 1967. This infestation may have had an adverse effect on seed germinability.

Seed collected when the moisture content of the samaras was over 145 percent varied in germinability all the way from zero to about 95 percent. Thus seed collectors should be cautioned to wait until the moisture content of the samaras falls to 145 percent.

Color Comparisons

Timing of harvests by field personnel would probably be based mostly on color of the samaras. The color changes were for the most part gradual, with a more abrupt change near the time of samara fall. The samaras were a bright green at the beginning

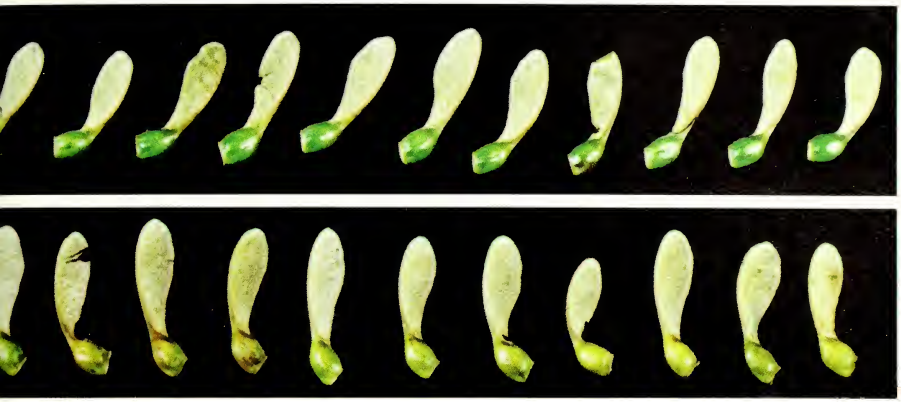


Figure 5.—Sugar maple samaras from the same tree at two stages of development. The top row shows them when they are bright green, before they are ripe. The samaras in the bottom row have turned yellowish green, and are ripe. At least 95 percent of the seeds from the samaras in the bottom row will germinate.

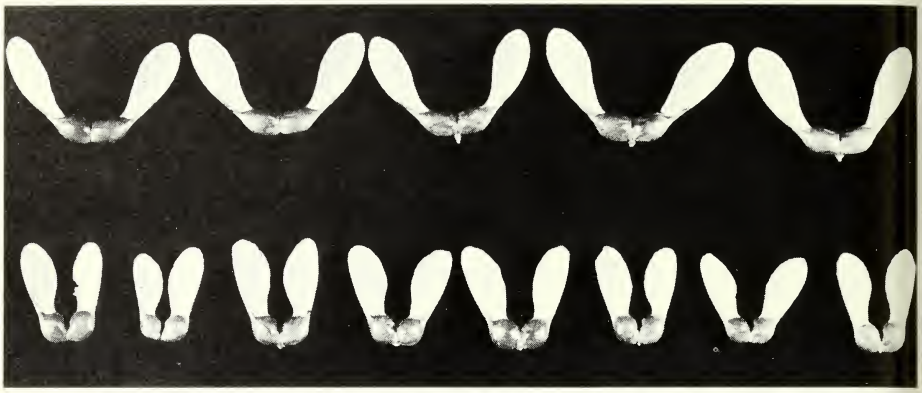
of the study, changing to yellowish green, and then to brown. By the time the majority of the samaras had changed from bright green to yellowish green (fig. 5), the seeds were fully ripened Once they have reached this condition they can be collected at any time until seedfall.

If the samaras have turned completely brown, they should be picked immediately. We found that the samaras will soon be shed after developing to this stage.

DISCUSSION

Seed ripening was much slower for the 1967 seed crop than for the 1964 seed crop. For the 1964 seed crop, germination reached 95 percent by the beginning of September for trees A and C and by late September for tree B. For the 1967 crop, none of these trees reached 95-percent seed germination until collections on 5 October. For the 22 individual collections made in 1964, 16 approached or exceeded 95-percent germination. Of the 22 collections made in 1967, only 4 approached or exceeded 95-percent germination. In 1964 there were 2 weeks when seeds

Figure 6.—Differences in the angles of attachment of samaras from different trees. Samaras in the top row are from tree B, in which the male portion of the flowers bloomed first and the seeds matured last. Samaras in the bottom row are from tree C, in which the female portion of the flowers bloomed first and the seeds matured first.



from all 3 trees germinated at least 95 percent, but in 1967 no single week's collection had seeds from all three trees germinate at this level.

Another factor apparently related to timing of seed maturity was noted: differences in the angles of attachment of the bodies of the samaras, which are relatively constant for individual trees (fig. 6), appear to be related to flower dichogamy. William J. Gabriel, geneticist at the Station's research unit at Burlington, Vermont, drew this conclusion from his previous research on the reproductive behavior of sugar maple.

Samaras from tree C (fig. 6, lower row) were derived from flower parts where the female portion bloomed first, while in tree B (fig. 6, upper row) the male portion bloomed first. Seeds of tree C always matured before those of tree B. Further study of this relationship is under way.

Because of the variability between trees in seed development, we found that collection has to be timed on an individual tree basis. Seeds will generally have reached their maximum germination potential when their moisture content has dropped below 145 percent or the samaras are yellowish green.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Distribution of PARQUET FLOORING During 1969

by William C. Miller

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-218
1972

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

FOREWORD

THIS IS THE THIRD IN A SERIES of papers dealing with the residential and commercial hardwood flooring industry. The first two paper are: PHYSICAL DISTRIBUTION OF OAK STRIP FLOORING IN 1969 (U.S.D.A. Forest Serv. Res. Paper NE-207) and DISTRIBUTION OF MAPLE STRIP FLOORING IN 1969. (U.S.D.A. Forest Serv. Res. Paper NE-215).

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MANUSCRIPT RECEIVED FOR PUBLICATION 4 MARCH 1971.

THE PARQUET INDUSTRY

KNOWLEDGE OF TRENDS AND WORKINGS of the industry is important to success in almost any business and the parquet flooring business is no exception. So we sent a questionnaire to all producers of hardwood parquet flooring in the U.S. to find out where and how much flooring is produced, where producers sell their product, and how producers approach merchandising and advertising.

DATA COLLECTION

Survey Procedure

The questionnaire was mailed to all manufacturers of residential or commercial hardwood flooring on 27 January 1970, and two follow-up mailings were made at 3-week intervals to nonrespondents. Finally a follow-up telephone survey was made to contact those who did not respond to the mailings. The following response was obtained:

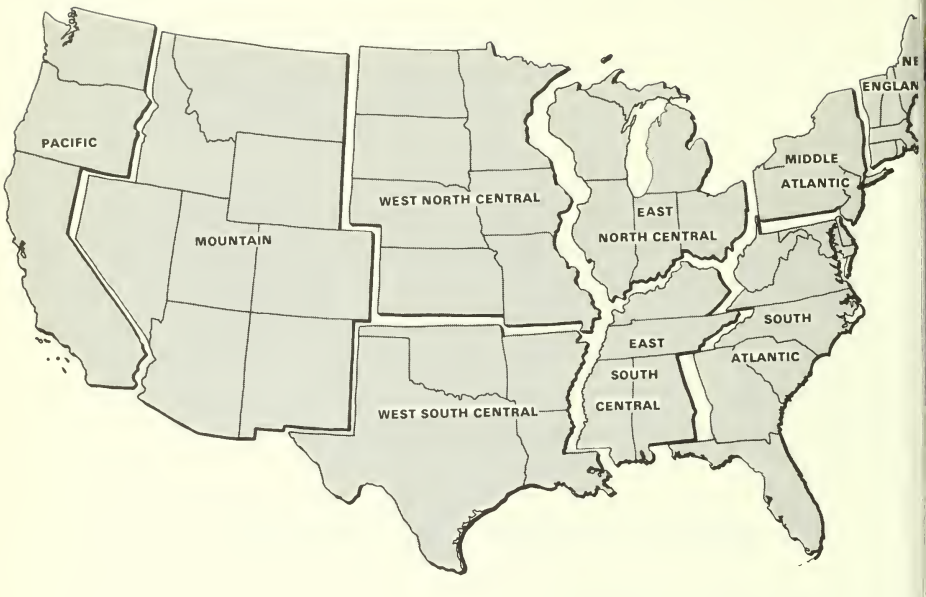
No. of firms	*Response*
9	Completed and returned the questionnaire.
3	Completed a part of the questionnaire.
1	Either was not in business or did not manufacture parquet flooring.
3	Provided no data.
16	TOTAL contacted.

Definition of Terms

Geographic Regions.—The nine regions used are those established by the Bureau of Census (fig. 1).

Production Region.—A production region is the region in which the flooring was manufactured and from which it was shipped.

Figure 1.—Composition of regions and geographic divisions.



Channels of Distribution.—Six channels are recognized as follows: 1. Builders, 2. Flooring subcontractors, 3. Retailers, 4. Wholesalers, 5. Nonstocking wholesalers, 6. Agents and brokers.

ADJUSTMENTS AND ASSUMPTIONS

Data were obtained on shipments by manufacturers of 22,213,900 square feet of hardwood parquet flooring. The parquet flooring data collected included hardwood unit block and mosaic parquet block floorings; it did not include hardwood laminated block flooring.

There are no formal statistical data on parquet flooring; however, the author, in consultation with industry sources, estimated the total U. S. parquet flooring shipments to be 27,200,000 square feet during 1969. Based on this, the sample

represents about 82 percent of the total. About 1,440,000 square feet[1] of parquet flooring imported into the U.S. during 1969 were not included.

The data are based on manufacturers' records of flooring shipments through the first transaction in the distribution process.

DISTRIBUTION

About 95 percent of the parquet flooring is oak, and most is produced in Tennessee, Arkansas, and Missouri. Due to the limited number of manufacturers within any one geographic region, the shipment data were combined for all manufacturers to avoid confidential disclosure of data on individual firms (fig. 2).

[1] U.S. Department of Commerce. U.S. IMPORTS FOR CONSUMPTION AND GENERAL IMPORTS TSUSA, 1969. Annual. Washington, D. C., Foreign Trade Division, Bureau of Census, p. 69, 1970.

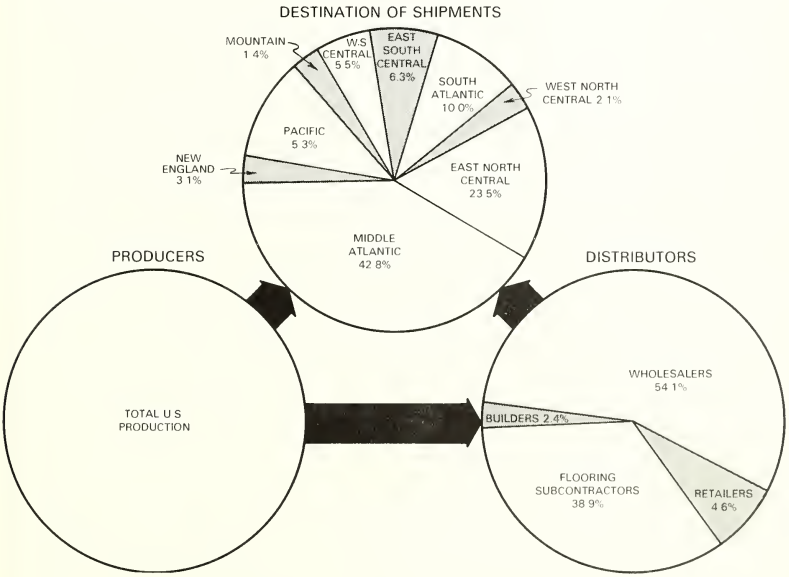


Figure 2.—Producers, distributors, and destination of shipments of parquet flooring during 1969.

Channels of Distribution

The distribution channels are often categorized into two groups: a distributor group comprised of builders, flooring subcontractors, retailers, and wholesalers who buy the flooring from the manufacturer and take title to it; and an intermediary group comprised of nonstocking wholesalers, and agents and brokers who act as marketing intermediaries and do not take title to the flooring. No parquet flooring was distributed by the intermediary group. Instead, all of the parquet flooring was distributed by the distributor group. Wholesalers distributed about 54 percent; flooring subcontractors, 39 percent; retailers, 5 percent; and builders, 2 percent (fig. 2 and table 1).

Wholesalers.—Of the 54.1 percent (12,012,400 sq. ft.) distributed by wholesalers, about 38 percent was shipped to the Middle Atlantic Region, 22 percent to the East North Central Region, 9 percent to each of the South Atlantic and Pacific Regions, 7 percent to the East South Central Region, 5 percent to each of the New England and West South Central Regions, and 2 percent to each of the West North Central and Mountain Regions.

Flooring subcontractors.—Of the 38.9 percent (8,634,800 sq. ft.) distributed through flooring subcontractors, 52 percent went to the Middle Atlantic Region, 26 percent to the East North Central Region, 12 percent to the South Atlantic Region, 6 percent to the West South Central Region, 1.9 percent to the West North Central Region, 1.6 percent to the East South Central Region, and less than 1 percent to each of the New England, Mountain, and Pacific Regions.

Retailers.—Of the 4.6 percent (1,023,400 sq. ft.) distributed by retailers, 29 percent went to the East South Central Region, 21 percent to the Middle Atlantic Region, 19 percent to the East North Central Region, 11 percent to the Mountain Region, 6 percent to the Pacific Region, 5 percent to each of the West North Central and South Atlantic Regions, 4 percent to the West South Central Region, and none to the New England Region.

Table 1.—Where distributors shipped their parquet flooring by geographic region, 1969[1]

Distributor	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total	Distribution total	U.S. total
	%	%	%	%	%	%	%	%	%	%	*M sq. ft.*	%
Builders	0	38.7	19.0	0	9.5	27.2	5.6	0	0	100.0	543.3	2.4
Flooring subcontractors	.6	52.0	26.4	1.9	11.5	1.6	5.7	*	.3	100.0	8,634.8	38.9
Retailers	0	20.6	19.0	5.0	5.0	29.1	3.8	11.3	6.2	100.0	1,023.4	4.6
Wholesalers	5.4	38.3	22.1	2.1	9.3	6.8	5.4	1.5	9.1	100.0	12,012.4	54.1
Nonstocking wholesalers	0	0	0	0	0	0	0	0	0	0	0	0
Agents & brokers	0	0	0	0	0	0	0	0	0	0	0	0
Total U. S.	3.1	42.8	23.5	2.1	10.0	6.3	5.5	1.4	5.3	100.0	22,213.9	100.0

[1] The parquet flooring data collected included hardwood unit block and mosiac parquet block floorings; it did not include hardwood laminated block flooring.

* Percentage figure is less than 0.05.

Builders.—Of the 2.4 percent (543,300 sq. ft.) distributed by builders, about 39 percent was distributed to the Middle Atlantic Region, 27 percent to the East South Central Region, 19 percent to the East North Central Region, 9 percent to the South Atlantic Region, 6 percent to the West South Central Region, and none to the New England, West North Central, Mountain, and Pacific Regions.

Destination of Shipments

About 86 percent of the total parquet flooring shipments went to the regions east of the Mississippi River (fig. 2 and table 2). About 43 percent (9,507,500 sq. ft.) was shipped to the Middle Atlantic Region, 24 percent to the East North Central Region, 10 percent to the South Atlantic Region, 6 percent to each of the East South Central and West South Central Regions, 5 percent to the Pacific Region, 3 percent to the New England Region, 2 percent to the West North Central, and 1 percent to the Mountain Region.

New England.—Of the 3.1 percent (688,600 sq. ft.) shipped to the New England Region, 93 percent was distributed by wholesalers and 7 percent by flooring subcontractors.

Middle Atlantic.—Of the 42.8 percent (9,507,500 sq. ft.) shipped to the Middle Atlantic Region, wholesalers distributed about 48 percent; flooring subcontractors, 47 percent; and builders and retailers, each 2 percent.

East North Central.—Of the 23.5 percent (5,220,300 sq. ft.) shipped to the East North Central Region, wholesalers distributed about 51 percent; flooring subcontractors, 43 percent; retailers, 4 percent; and builders, 2 percent.

West North Central.—Of the 2.1 percent (466,500 sq. ft.) shipped to the West North Central Region, wholesalers distributed about 53 percent; flooring subcontractors, 36 percent; and retailers, 11 percent.

South Atlantic.—Of the 10.0 percent (2,221,400 sq. ft.) shipped to the South Atlantic Region, wholesalers distributed about 50 percent; flooring subcontractors, 45 percent; and builders and retailers, each 2.3 percent.

Table 2.—Geographic shipment destinations of parquet flooring by distributor, 1969[1]

Shipment destination by geographic region	Builders	Flooring sub-contractors	Retailers	Wholesalers	Nonstocking wholesalers	Agents & brokers	Total	Regional shipment total	Percent of U.S. total
	%	%	%	%	%	%	%	*M sq. ft.*	%
New England	0	7.4	0	92.6	0	0	100.0	688.6	3.1
Middle Atlantic	2.2	47.2	2.2	48.4	0	0	100.0	9,507.5	42.8
East North Central	2.0	43.5	3.7	50.8	0	0	100.0	5,220.3	23.5
West North Central	0	36.0	11.0	53.0	0	0	100.0	466.5	2.1
South Atlantic	2.3	45.0	2.3	50.4	0	0	100.0	2,221.4	10.0
East South Central	10.5	10.1	21.2	58.2	0	0	100.0	1,399.5	6.3
West South Central	2.5	40.5	3.2	53.8	0	0	100.0	1,221.8	5.5
Mountain	0	.7	38.3	61.0	0	0	100.0	311.0	1.4
Pacific	0	2.2	5.4	92.4	0	0	100.0	1,177.3	5.3
Total U.S.	2.4	38.9	4.6	54.1	0	0	100.0	22,213.9	100.0

[1] The parquet flooring data collected included hardwood unit block and mosaic parquet block floorings; it did not include hardwood laminated block flooring.

East South Central.—Of the 6.3 percent (1,399,500 sq. ft.) shipped to the East South Central Region, wholesalers distributed about 58 percent; retailers, 21 percent; builders, 11 percent; and flooring subcontractors, 10 percent.

West South Central.—Of the 5.5 percent (1,221,800 sq. ft.) shipped to the West South Central Region, wholesalers distributed about 54 percent; flooring subcontractors, 40 percent; and builders and retailers, each 3 percent.

Mountain.—Of the 1.4 percent (311,000 sq. ft.) shipped to the Mountain Region, wholesalers distributed 61 percent; retailers, 38 percent; and flooring subcontractors, 1 percent.

Pacific. —Of the 5.3 percent (1,177,300 sq. ft.) shipped to the Pacific Region, wholesalers distributed about 92 percent; retailers, 5.4 percent; flooring subcontractors, 2.2 percent; and builders, none.

Patterns of Distribution

Three questions pertaining to past and expected changes in the patterns of distribution were asked of manufacturers. First: Has the geographic distribution of shipments changed since 1960? Four manufacturers reported moderate changes in the geographic distribution of their shipments; two reported considerable change; and one reported no change. The changes were mainly increases in shipments to regions east of the Mississippi River and decreases to regions west of the Mississippi River.

The second question was: Have the channels of distribution changed since 1960? Five of the nine manufacturers indicated moderate changes; and four reported no change. Changes were mainly a transfer from retail yards to flooring subcontractors because of a lack of attention given to parquet flooring by retailers and because of more direct sales to speciality flooring distributors, larger purchasers, and mobile home manufacturers.

The third question was: Compared to 1969, what changes in the distribution system are expected by 1975? Five man-

ufacturers expect moderate changes by 1975; and four expect no change. Manufacturers expect to channel more flooring through the distributors who have the ability to provide both professional supervision and counseling to the consumers. They also expect an increase in direct sales to modular or unitized home builders, mobile home manufacturers, builders, flooring subcontractors, and larger purchasers.

PROMOTIONAL PRACTICES

Four questions pertaining to advertising were asked of manufacturers. First, what media were used? The nine manufacturers that responded used several media: eight advertised through brochures and pamphlets; seven advertised in trade papers, magazines and journals; six advertised in trade directories; four advertised in the telephone directory; four advertised in other media such as trade and home shows, Sweet's Catalog, and through direct contact; three advertised in consumer magazines; two advertised in regular newspapers; and one did not advertise.

The second question was: Which media was the most effective? Five manufacturers considered brochures and pamphlets the most effective because they give more complete consumer information and reach the people who make the buying decisions; one considered the trade papers, magazines, and journals most effective; one considered consumer magazines most effective; and one considered other media such as direct personal contact most effective.

The third question was: Which media was least effective? Three considered telephone directories to be least effective because the market coverage is too limited; two considered trade directories least effective; and one considered regular newspapers least effective.

The fourth question was: Do you advertise cooperatively with the distributors? Six of the nine manufacturers reponded, and all of those advertised cooperatively with the distributors.

DISCUSSION AND SUMMARY

Essentially all of the parquet flooring is produced in the Southern and Appalachian hardwood areas of the United States. The Middle Atlantic, East North Central, and South Atlantic Regions were first, second, and third, respectively, in total shipments; and the Mountain Region was last.

The channels of distribution are dominated by wholesalers and flooring subcontractors; however, wholesalers are stronger in the New England, East South Central, Mountain, and Pacific Regions; and wholesalers and flooring subcontractors are about equal in the Middle Atlantic, East North Central, and South Atlantic Regions.

When queried about the usage of different types of advertising media, parquet manufacturers indicated they used (in decreasing order) brochures and pamphlets, trade magazines, trade journals, trade publications, trade directories, and exhibits at trade and home shows. Manufacturers considered these advertising media to be the most effective because they give considerable consumer information and reach the right people—the people who make the buying decisions. Manufacturers considered both telephone directories and trade directories to be the least effective media because they are too localized and are not used enough by consumers.

Most parquet manufacturers reported that they use cooperative advertising with their distributors.

According to most parquet manufacturers, the geographic market area and channels of distribution for parquet flooring have changed since 1960 and are expected to change even more by 1975. From 1960 to 1969, increases in shipments to regions east of the Mississippi River and decreases in shipments to regions west of the Mississippi River accounted for most of the geographic distribution changes.

Parquet manufacturers reported that from 1960 to 1969, distribution shifted from retail lumber yards to flooring subcontractors because flooring subcontractors provide better

consumer service. Manufacturers also reported more direct sales to speciality flooring distributors, larger purchasers, mobile home manufacturers, and builders of modular or unitized units.

By 1975, manufacturers expect to channel a greater proportion of the flooring through the distributors who have both the expertise and the facilities to offer consumers a complete floor system.

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Pennsylvania's Private Woodland Owners—

A Study of the Characteristics, Attitudes, and Actions of an Important Group of Decision-Makers

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by David N. Larsen and David A. Gansner

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-219
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Pennsylvania's Private Woodland Owners—

A Study of the Characteristics, Attitudes, and Actions of an Important Group of Decision-Makers

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AN EXPANDING MEGALOPOLITAN population is going to look to forest lands in the Northeast for a greater supply of commodities and services. Will they find what they are looking for? The answer to this question depends greatly on the attitudes and actions of woodland owners. They control the resource, and their decisions will determine its use.

The policies and operations of most public and large corporate owners of forest land are matters of record or can be readily determined. But little is known about the characteristics, attitudes, and actions of farmers, small businessmen, laborers, professionals, clerks, retirees, housewives, and other private noncorporate owners who collectively own most of the woodland in the Northeast. Until more is known about these people, meaningful assessments of the availability of forest products and services will be impossible. To help fill the knowledge gap, we conducted this study of private non-industrial woodland owners in Pennsylvania.

Study Approach

There are approximately 300,000 private non-corporate woodland owners in Pennsylvania (*3*). It was not feasible to attempt to contact all of these individuals, so some method of sampling had to be devised. Previous research suggests that owner decisions regarding the management and use of woodland are related to size of holding (*1*) (*2*). Accordingly, we designed a sampling technique that insured an adequate stratification of owners by woodland size class.

Six hundred forested points were systematically selected and marked on aerial photographs. The sample was equally proportioned among three regions of Pennsylvania exhibiting contrasting structures of socio-economic activity (fig. 1).

The Southwest Region, except for the cities of Altoona and Johnstown, is a typically rural area. Its hills are covered with trees and the utilization of timber contributes significantly to the local economy. The Southeast Region exhibits a mixed setting of suburban fringe and intensive agriculture. Woodland is sparse and is found in small scattered tracts. The Pocono Region is densely forested. It is in close

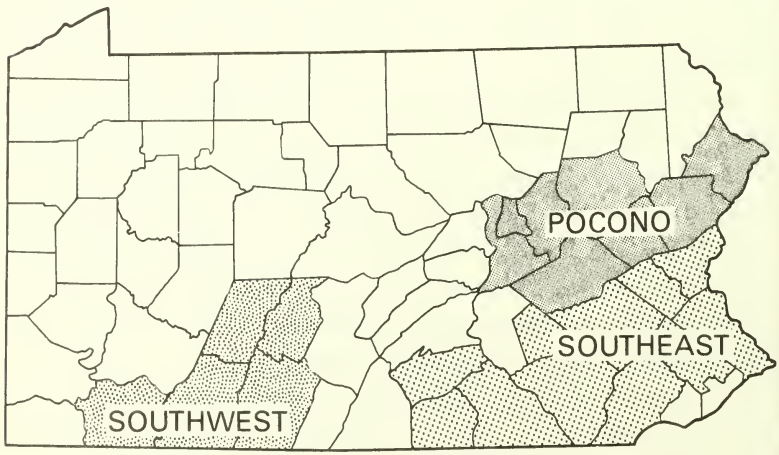

Figure 1.—The study regions.

proximity to large metropolitan centers and is best known for its recreational facilities.

Names and addresses of the owners of the photo point locations were obtained from county assessment offices. Questionnaires were mailed to the owners, and many of those who did not respond were contacted by phone. A total of 394 owners provided data for this analysis (table 1).

Woodland Owner Characteristics

Occupation, Income, Age, and Education

Woodland owners are in many diverse fields of endeavor. Our sample includes occupations ranging from bartender to wild animal trainer. A large number of owners fall into the category known as white collar workers—doctors, teachers, township supervisors, store owners, secretaries, salesmen, etc. (table 2). Two-thirds of the large owners and one-third of the small and medium owners are in this occupation class.

There is a very significant relationship between owner income and size of woodland holding. Sixty-five percent of the large woodland owners received a gross household income of $10,000 or more in 1968 (table 3). Only 30 percent of the small owners were this affluent.

Any effective planning for the availability and use of private forests must involve woodland owners over 50 years of age. They represent an overwhelming majority of the owners in each acreage class (table 4). Very few owners are under 30.

Large owners have more formal education (table 5). More than four-fifths of them have attended high school, and more than half of these individuals have been to college. Only one-fourth of the small owners and one-third of the medium owners have attended college.

Tenure

Our sample includes some people who have owned woodland for less than 1 year and others who have owned woodland for more than 50 years. The great majority have been woodland owners for more than 10 years (table 6). About half of the individuals in each acreage class have had tracts for more than 20 years.

Mortgages, leases, and other legal commitments on the woodland can have an important impact on owner decisions regarding woodland use and development. However, our study indicates that few owners are subject to these encumbrances (table 7).

There is a definite relationship between size of holding and type of ownership (table 8). Practically all of the small holdings are owned by individuals and family units. Partnerships are more prevalent among the medium and large owners.

Owners of small tracts live closer to their woodlands (table 9). Seventy-two percent of the small owners live on or within a mile of their closest tract. Most of the large owners live at least a mile away, and many reside more than 25 miles away from their nearest woodland.

A preponderance of the land owned by large and medium woodland owners is in forest (table 10). Four-fifths of the large owners indicate that woodland accounts for more than 75 percent of their total land holding. Small woodland owners use a greater proportion of their land for purposes such as residence and farming. Thus a smaller percentage of their holdings are in tree cover.

Woodland Owner Attitudes and Actions

Uses of Woodlands

Woodland owners listed the most important recent past uses of their woodland, and we classified them into five general categories—personal recreation, production of forest products and services, speculation in land value, satisfaction of ownership, and permanent residence (table 11).

This classification reveals some significant findings. Small woodland owners listed permanent residence as the primary use and ranked satisfaction of ownership second and personal recreation third. Medium owners gave nearly equal weight to all five uses. Large owners said that speculation in land values and production of forest products and services (both income producing motives) were most important and ranked satisfaction of ownership a strong third.

Comparison of past use (table 11) with future use intent (table 12) indicates that woodland owners in each size class will place more emphasis on the output of products and services and land values in the years ahead. They apparently would like to derive more income from their forest properties than they have in the past.

Sales of Forest Products

Current Selling Activity.—Forest product selling activity is related to size of holding. Large woodland owners sell more frequently than small and medium owners (table 13). Nearly half of the large owners sold products in the last 5 years. Only 29 percent of the medium owners and 9 percent of the small owners reported product sales.

Our data will not permit complete analyses of the quantity and value of recent sales. However, a range can be presented. The most active seller sold $230,000 worth of sawlogs

and mine timbers in the last 5 years. The least active seller sold $50 worth of fence posts. One individual received $370 for rhododendron and laurel plants dug from his woodland.

Large owners received more professional help with product sales than small and medium owners (table 14). Nearly three-fourths of the sellers in the large owner category received assistance. The types of assistance included boundary surveys, selection and marking of trees, and sales volume estimates.

Those owners who did not sell forest products in the last five years were asked to list the prime reasons for not selling. We received a variety of replies. These responses were sorted into three general categories (table 15). Nearly three-fifths of the nonsellers who own large woodland acreages indicated they had nothing of value to sell. Two-fifths (a plurality) of the nonsellers in the small and medium woodland acreage classes said they didn't want to sell and that other interests such as maintenance of natural setting and protection of wildlife habitat precluded product sales.

Only a very small percentage of owners who did not sell forest products in the past 5 years tried to find buyers for their products. But at least 32 percent of the non-selling owners in each woodland acreage class were contacted by buyers (table 16). Buyers approached half of the nonsellers who own large woodland acreages.

Plans for Future Sales.—Large owners are more inclined to sell forest products in the years ahead than small and medium owners (table 17). Nearly two-fifths of the large owners intend to sell. Less than one-fourth of the medium owners and only one-tenth of the small owners plan sales. Twenty-eight percent of the owners in each size category are not certain of their selling plans.

There appears to be a strong relationship between past selling activity and future sales intent. Owners who sold in the recent past are more inclined to sell in the future.

About four-fifths of those owners with a potential interest

in future product sales indicate a need for information and services (table 18). What they would want most is help in selecting and determining the value of salable products. Some would also require price information, aid in finding a buyer, and woodland boundary surveys.

Those owners who definitely do not intend to sell forest products in the near future were asked to list the prime reasons for not wanting to sell. Reasons were basically the same as those given by owners who did not sell in the past. A plurality of the large and medium owners who do not plan product sales said they would have nothing of value to sell in the next 5 years (table 19). A plurality of the small owners indicated that other uses will preclude product removals.

Forest Management Practices

More large owners practiced forestry than small and medium owners. About half of the large owners have undertaken some form of forest management in the past 5 years (table 20). Tree planting was by far the most popular practice among all owners. But a significant number have also developed management plans, taken inventory of their forest stands, and thinned out trees to provide growing space. There was great variation in the kind and extent of practice accomplishment. The most active owner in our sample thinned a 1200-acre tract and sold the merchantable volume for mine timbers and sawlogs. Another owner only planted a half acre of pine.

Most of the owners in our sample said they did not obtain information about the management and marketing of forest products during the past 5 years (table 21). Receipt of information was related to size of woodland holding. One-third of the large owners, but only about 10 percent of the small and medium owners, obtained this kind of information. Those who did obtain information listed the Pennsylvania Department of Environmental Resources and private consultants as primary sources.

Only a very small percentage of all the owners entered into formal government programs (for example, the Agricultural Conservation Program) that provide technical or cost sharing assistance with woodland projects (table 22).

Plans for Holding Woodland

Some owners are uncertain as to whether or not they will hold on to their woodlands in the next few years (table 23). But most of them—four-fifths of the small owners and three-fifths of the medium and large owners—definitely plan to keep all of their woodlands. Nearly one-fourth of the large owners intend to sell part or all of their holdings.

Summary

This study provides a wealth of current information about the characteristics, attitudes, and actions of private noncorporate woodland owners in Pennsylvania. Perhaps most important is its documentation of the many basic differences between owners of small, medium, and large tracts of woodland. We found, for example, that larger owners (500 acres or more woodland):

- have higher incomes
- have more formal education
- live farther from their woodlands
- are more interested in the income producing potential of their forest tracts
- sell forest products more frequently
- undertake forest management more often

As a result of this analysis, we have a sounder basis for assessing the role of the private woodland owner as a supplier of forest products and services.

We are now subjecting the study results to a multivariate analysis in an attempt to develop models for explaining and predicting woodland owner actions.

Tabular Data

Table 1.—The sample of owners by region and size of woodland holding

[Number of owners]

Regions	Woodland acreage class			
	Small 1 - 99	Medium 100 - 499	Large 500 and more	Total
Southwest	55	65	19	139
Southeast	105	24	5	134
Pocono	64	35	22	121
Total	224	124	46	394

Table 2.—Occupation, in percent

Main occupation	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
White collar workers[1]	32	32	68
Blue Collar workers[2]	20	19	4
Farmers	21	23	4
Retired individuals	15	16	20
Others[3]	12	10	4
Total	100	100	100

[1] White collar workers include professional and technical people, managers, officials and proprietors, clerical workers, and sales workers.

[2] Blue collar workers include craftsmen and foremen, operatives (e.g. truck drivers), and laborers.

[3] Others include service workers, housewives, and disabled and unemployed individuals.

Table 3.—Income, in percent

Income class[1]	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Less than $5,000	39	37	13
$ 5,000 - $ 9,999	31	25	22
$10,000 - $19,999	17	15	24
$20,000 and more	13	23	41
Total	100	100	100

[1] Total gross household income from all sources in 1968. Includes salaries, wages, dividends, income from business, social security, etc.

Table 4.—Age, in percent

Age class	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Under 50	29	30	22
50 - 59	29	32	43
60 and over	42	38	35
Total	100	100	100

Table 5.—Formal education, in percent

Highest level attended	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Grade school	35	36	18
High school	40	31	28
College	25	33	54
Total	100	100	100

Table 6.—Duration of ownership, in percent

Duration (years)	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
10 or less	27	32	15
11 to 20	20	22	35
More than 20	53	46	50
Total	100	100	100

Table 7.—Encumbered status of woodlands, in percent

Status	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Encumbered[1]	14	15	7
Unencumbered	86	85	93
Total	100	100	100

[1] Mortgages, leases, and other legal commitments.

Table 8.—Ownership type, in percent

Type	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Individual or family	95	81	65
Partnership[1]	5	19	35
Total	100	100	100

[1] Includes a few undivided estates.

Table 9.—Distance from residence to nearest woodland, in percent

Distance to nearest woodland	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Live on or within 1 mile	72	60	35
1 - 25 miles	21	31	39
More than 25 miles	7	9	26
Total	100	100	100

Table 10.—Woodland as a percent of total land acreage owned, in percent

Percent of land in woodland	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
1 - 25	29	5	0
26 - 50	24	23	7
51 - 75	16	21	15
76 - 100	31	51	78
Total	100	100	100

Table 11.—Most important uses of woodlands in the past 5 years, in percent

Uses	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Permanent residence	36	18	4
Satisfaction of ownership	28	19	23
Personal recreation[1]	22	21	12
Production of forest products and services[2]	7	22	30
Speculation in land value	7	20	31
Total	100	100	100

[1] Summer home, camping, fishing, hunting, etc.
[2] Timber, maple syrup, Christmas trees, commercial recreation, etc.

Table 12.—Most important intended uses of woodlands in the next 5 years, in percent

Uses	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Permanent residence	33	17	3
Satisfaction of ownership	17	11	16
Personal recreation[1]	21	19	14
Production of forest products and services[2]	14	31	39
Speculation in land value	15	22	28
Total	100	100	100

[1] Summer home, camping, fishing, hunting, etc.

[2] Timber, maple syrup, Christmas trees, commercial recreation, etc.

Table 13.—Forest products selling activity during the past 5 years, in percent

Status	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Sellers	9	29	46
Nonsellers	91	71	54
Total	100	100	100

Table 14.—Sellers who received professional help with forest product sales during the past 5 years, in percent

Received help	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	25	20	72
No	75	80	28
Total	100	100	100

Table 15.—Prime reasons for not selling forest products in the past 5 years, in percent

Reasons	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Timber immature, nothing to sell	37	37	59
Didn't want to sell, conflicting uses precluded product removal	40	40	8
Other[1]	23	23	33
Total	100	100	100

[1] "Didn't need the money," "Didn't know how to go about selling," "Woodland too far from road," "Prices too low," and a variety of other reasons.

Table 16.—Nonsellers contacted by forest product buyers during the past 5 years, in percent

Contacted by buyers	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	32	32	50
No	68	68	50
Total	100	100	100

Table 17.—Plans for selling forest products in the next 5 years, in percent

Plan to sell	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	10	23	39
No	62	49	33
Not certain	28	28	28
Total	100	100	100

Table 18.—Potential seller need for assistance with product sales during the next 5 years, in percent

Need help	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	76	83	81
No	24	17	19
Total	100	100	100

Table 19.—Prime reasons for not planning to sell forest products in the next 5 years, in percent

Reasons	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Timber is immature, nothing to sell	24	44	43
Conflicting uses preclude product removal	45	38	28
Other[1]	31	18	29
Total	100	100	100

[1] "Won't need the money," "Woodland too far from road," "Won't get the price I want," and a variety of other reasons.

Table 20.—Use of forest management practices during the past 5 years, in percent

Practiced forest management	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	35	37	52
No	65	63	48
Total	100	100	100

Table 21.—Receipt of management and marketing information during the past 5 years, in percent

Received information	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	9	12	33
No	91	88	67
Total	100	100	100

Table 22.—Receipt of government program assistance (technical or cost sharing) with woodland projects during the past 5 years, in percent

Received government assistance	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Yes	3	7	11
No	97	93	89
Total	100	100	100

Table 23.—Plans for holding woodland during the next 5 years, in percent

Plans	Woodland acreage class		
	Small 1 - 99	Medium 100 - 499	Large 500 and more
Will definitely keep all	79	59	59
Will sell part or all	4	13	24
Not certain	17	28	17
Total	100	100	100

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

INSECTS

That damage White Oak acorns

By Lester P. Gibson

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-220
1972

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

THE AUTHOR

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Phenotypic Selection in
SUGAR MAPLE
for superior sap sugar production

by William J. Gabriel

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-221
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MANUSCRIPT RECEIVED FOR PUBLICATION 18 JUNE 1971.

Phenotypic Selection in SUGAR MAPLE for superior sap sugar production

ALTHOUGH THE MANUFACTURE of maple syrup is one of our oldest industries, there is little past evidence of organized efforts for improving it. New developments have been due mainly to individual Yankee ingenuity rather than through collective efforts. Now the problems of the industry are receiving the attention of scientists in a number of states where syrup-making is of economic importance.

Our sugar maple sap production project at Burlington, Vermont, is carrying out a research program to reduce the cost of producing maple syrup. One purpose of this program is to develop strains of trees that are superior in sap sugar production.

A problem common to nearly all tree-improvement programs is to find and progeny-test superior phenotypes. It is particularly important that the selection method used will give reasonable assurance that the phenotypes owe their superiority mainly to genetic rather than environmental factors.

This is a report on the results of the sugar maple selection program at Burlington, Vermont. Because of its possible value to other forestry workers, the method used in making the selections has been treated in detail.

BACKGROUND

Previous studies in sap sugar production have dealt mainly with the relations between tree characteristics and sap sweetness.

Morrow (*1955*) considered that the open growth of trees favored increased sap volume rather than sugar content in sap. A strong correlation between sap sugar content and sap volume yield was found among trees studied by Marvin et al. (*1967*).

Anderson (*1951*), in a study of environmental effects on sap sugar content, found that crown size of trees was an important factor. Morrow (*1955*) reported that crown length was more closely related with sugar content of sap than was crown diameter, but that large variations in sap sweetness that he observed between trees were due primarily to factors other than those related to tree crowns.

Moore et al. (*1951*) noted no relation of variation in sap sugar content of trees to difference in site or other environmental factors. They suggested that the observed variation might be due to genetic influence.

The application of commercial fertilizers resulted in a significant increase in sap sugar concentration during the sap-flow season immediately after fertilization (*Watterston et al. 1963*). However, a significant decrease in the sugar content of sap was noted during the second sap-flow season.

Consistent season-to-season performances of trees in the production of sap sugar was reported by Taylor (*1956*). When trees were ranked according to sugar content in sap, the same individuals appeared in the same relative positions each year. Taylor observed that phenotypes within the same sugarbush may have sap sugar differences of more than 100 percent. Marvin (*1957*) also noted consistent year-to-year yields of sap sugar in the trees he studied and suggested that this variation was due to inherited traits.

Preliminary reports on the development of procedures used and the problems associated with the selection of sugar ma-

ples for superior sap sugar production have been made by Gabriel (*1964*) and by Gabriel and Howe (*1968*).

METHODS

Organization and Training of Fieldmen

To carry out field work, we enlisted the cooperation of state forestry and extension service organizations, educational institutions, and sugar producers in the major sugar-producing states in the Northeast—Maine, Massachusetts, New Hampshire, New York, Pennsylvania, and Vermont. Committees were set up in each state to act as liaison between the genetics staff at Burlington and the fieldmen, to help disseminate information, and to act as clearing houses for collected data.

Training of 70 participating fieldmen, primarily service foresters and extension agents, was conducted in each state. A short course in genetics was included at each training session, to give the fieldmen a better understanding of the objectives of the program and to explain why it was necessary to adhere closely to the selection method as it was outlined.

Field Selection

Information from preliminary studies provided the basis for developing procedures and criteria for making selections. It seemed best to base selections on direct differences between selected trees and the average performances of adjacent trees, rather than indirectly through comparisons with stand averages, which could be influenced by a wider variety of environmental factors.

(Using the classical approach to selection—computing an average for a population and then selecting phenotypes that exceed the average by a chosen level—would make it difficult to minimize the environmental influences on sugar production because of frequent changes in stand density, site quality, and size and age classes of trees.)

In the method finally adopted, no predetermined absolute level of sap sugar had to be met by a tree before it would qualify as a selection. With a hand refractometer (fig. 1), the trees in a sugarbush were tested along a transect until one was encountered that measured at least 0.5 percent sweeter in sap sugar than the tree previously tested.

Measurements were then made on four or five adjacent and surrounding trees of similar appearance (standards), and their average sap sugar content was computed. Any tree that met the criteria of (1) being at least 30 percent above the average of the standards and (2) exceeding the sweetest of the standards by a minimum of 0.5 percent was selected as a superior phenotype (fig. 2). The number of standards was occasionally reduced to two or three trees because of a lack of individuals similar to the selected phenotypes.

Normally, no more than 100 trees were tested in the initial visit to a sugarbush. This enabled the fieldmen to visit larger numbers of bushes and resulted in a more widespread survey of the general area and more information about variation within and between states. The data that were collected,

Figure 1.—By using a hand refractometer, only one drop of sap is required to determine the sap sugar content of the tree.

Figure 2.—The superiority in sap sugar produced by the selected tree, indicated by the arrow, ranged from 46 to 68 percent above the average of the adjacent standard trees over a 4-year period.

along with information pertinent to each sugarbush, were entered on separate forms (fig. 3).

Selected trees and their standards received several sap sugar tests, and the results were entered on individual tree-record forms (fig. 4). Tests on each selection unit (the selected tree and its surrounding standard trees) were made within the same hour to minimize any variation in sap sugar associated with time of testing. All selected trees and their standards were suitably marked and mapped for later identification.

Final Screening

Since the success of the tree-improvement program hinged on the genetic worth of the phenotypic selections, the selected trees were subjected to a critical final screening by a geneticist from the Burlington office. The primary purpose

12-63 Sugarbush Number

#2

Do not write in this space

SURVEY RECORD FORM

8c

/__/ SUGARBUSH /__/ ROADSIDE OR FENCELINE TREES

Name of Owner: Leach (Last Name) Carrol (First Name) (Initial)

Address: West Enosburg, Vermont

Location of Bush if different from owner's address:

100-Tree Sample

Tree No.		Tree No.		Tree No.		Tree No.		Tree No.	
1.	2.6 %	21.	3.0 %	41.	3.0 %	61.	4.0 %	81.	3.6 %
2.	2.2	22.	3.0	42.	4.0	62.	3.0	82.	3.8
3.	3.0	23.	3.0	43.	2.6.	63.	4.0	83.	3.0
4.	3.0	24.	2.0	44.	3.0	64.	4.0	84.	3.6
5.	2.8	25.	2.0	45.	2.2	65.	3.8	85.	3.8
6.	3.0	26.	3.0	46.	2.2	66.	4.6	86.	2.6
7.	5.0	27.	2.8	48.	2.0	68.	4.0	88.	3.6
8.	3.4	28.	2.8	48.	2.0	68.	4.0	88.	3.6
9.	3.0	29.	3.8	49.	3.8	69.	4.2	89.	3.0
10.	3.0	30.	3.2	50.	2.8	70.	4.0	90.	3.4
11.	2.6	31.	2.2	51.	3.2	71.	3.8	91.	3.0
12.	2.4	32.	2.4	52.	3.4	72.	4.0	92.	5.0
13.	4.0	33.	2.4	53.	4.0	73.	3.0	93.	4.0
14.	4.0	34.	3.0	54.	3.0	74.	3.0	94.	3.0
15.	3.0	35.	3.8	55.	3.0	75.	5.0	95.	3.0
16.	4.0	36.	2.8	56.	4.2	76.	4.0	96.	3.2
17.	3.4	37.	2.8	57.	3.0	77.	3.0	97.	4.4
18.	3.2	38.	4.2	58.	3.6	78.	4.0	98.	3.4
19.	3.0	39.	3.6	59.	4.0	79.	4.0	99.	3.8
20.	2.4	40.	2.0	60.	3.2	80.	2.2	100.	3.0

Date: 4-20-63 Time Started: 2:00 P.M. Time Completed: 4:00 P.M.

By J. P. Harrington Title Forestry Technician

Remarks: Sugarbush made up mainly of old, open-grown trees.

Figure 3.—Completed record showing sap sugar test data and other information pertinent to the sugarbush.

of the screening was to evaluate the selected trees and their standards in terms of their similarities and differences and to derive an index figure that would be indicative of how well they compared with each other (fig. 4). The greater their similarities, the smaller would be the index number and the more valid would be the comparison between them for sap sugar production. Thus the screening procedure was a graduated series of penalties against a field-selected tree as it departed from its standards in appearance.

Vt. (12-63); 1(14-63)
Survey Number

4
Catalogue Number

FINAL FIELD SCREENING FORM

9a.

SUGAR MAPLES SELECTED FOR HIGH SAP SUGAR CONCENTRATION

Name of Tree Owner: Leach (Last Name) Carrol (First Name) Initial

Address: West Enosburg, Vermont

COMPARATIVE PERFORMANCE: SELECTED TREES VS. STANDARDS

1. Sap Sugar Concentration

		Percent Sugar						
	Selected	Standards					Standard	Difference
Date of Test	Tree	1	2	3	4	5	Average	Percent
3/11/63	6.2	4.0	3.2	4.0	3.7		3.7	67
4/15/63	5.4	3.5	3.0	3.0	3.3		3.2	68
4/16/63	5.2	3.4	3.0	2.9	3.2		3.1	67
4/6/64	5.4	4.7	3.0	3.3	3.0		3.5	54
4/8/64	5.1	4.2	2.6	3.4	2.9		3.2	59
4/10/64	5.2	4.7	2.8	2.7	2.8		3.3	57
3/9/65	5.3	4.2	4.0	3.4	2.8		3.4	56
3/19/65	6.0	4.9	4.3	4.0	3.1		4.1	46
4/12/66	6.3	4.4	4.1	3.5	3.7		3.8	65

2. Environment and Morphology Comparison of Standards and Selected Tree

							Total
(1) DBH	Inches	22	22	27	23	18	
	Index		0	2	0	1	3
(2) Height	Feet	72	82	80	74	81	
	Index		1	1	0	1	3
(3) Crown			0	0	0	1	1
(4) Insect Damage			0	0	0	0	0
(5) Disease Damage			0	1	0	0	1
(6) Topography			0	0	0	0	0
(7) Distribution		0	0	0	0	0	0
						Total Index	8

(3)-(7) Only the index number is entered.

Remarks: Crown size of Standard #4 smaller than selected tree. Standard #2 has small conk on trunk. Negatives in file.

Figure 4.—Completed record showing individual performances of the selected tree and its standards, together with the final screening data.

Standard trees were scored on how near they approached the selected tree in height, diameter, crown shape, crown size, and insect and disease damage. Standards were also scored on how well they were distributed about the selected tree and on their topographic relation to the selected tree (table 1).

I realize that certain unknown factors affecting sap sugar content may not have been considered in the screening proc-

Table 1.—Criteria assigned for determining index number for characters used in screening sugar maples selected for superior sap sugar production.

Character of factor	Index No.	Limits
Diameter	0	± 0-10% of selected tree diameter.
	1	± 11-20% of selected tree diameter
	2	± 21-30% of selected tree diameter.
	3	± 31% and over selected tree diameter.
Height	0	± 0-10% of selected tree height.
	1	± 11-15% of selected tree height.
	2	± 16-20% of selected tree height.
	3	± 21% and over selected tree height.
Distribution	0	Within 0-25 feet of selected tree.
	1	Within 26-40 feet of selected tree.
	2	Within 41-60 feet of selected tree.
	3	Beyond 60 feet of selected tree.
Crown	[1]0	Completely comparable to selected tree.
Insect damage	1	Some variation but still considered comparable.
Disease damage	2	Considerable variation, comparability questionable.
Topography	3	Not comparable to selected tree.

[1] Criteria limits 0 through 3 assigned to each character from crown through topography.

Under Remarks on Final Field Screening Form (fig. 4), it was indicated how the standard differed from the selected tree in the last 4 characters.

ess. However, in conjunction with the data on sap-sweetness tests, the screening provided a base for eliminating those field selections that appeared to have little potential genetic value.

The characters of height and diameter and the distribution of standards about the selected trees were measured by instruments. Scoring of the remaining characters was based on the judgment of the screening geneticist. Since both the standards and the selected trees were in the same view, any

pronounced variability in these characteristics became quite apparent and was judged by eye.

RESULT AND DISCUSSION

The success of the selection method was reflected in the widespread response from personnel in each of the six participating states. Seventy fieldmen visited 279 different sugarbushes over a 4-year period. Tests for sap sugar content were made on 21,080 trees, from which 319 field selections were made (table 2), representing 1.5 percent of the trees tested.

A number of the selected trees were dropped before screening because of (1) failure to meet the selection criteria, (2) extreme morphological differences between corresponding standards, (3) an excessive amount of disease, and (4) lost field identification. In a few instances trees were lost when they were cut by the owners. Eighty-two trees were dropped from the selection roster, leaving 237 to be screened.

In the screening process, each selected tree was visited by

Table 2.—Summary of survey-selection and screening results according to state

State	Sugarbushes surveyed	Trees tested	Field selections		Final selections[1]	
	No.	*No.*	*No.*	*Pct.*	*No.*	*Pct.*
Vermont	102	7,426	126	1.7	18	0.24
New York	72	4,896	74	1.5	15	.31
Pennsylvania	44	3,671	29	.8	7	.19
Massachusetts	35	2,537	34	1.3	6	.24
New Hampshire	18	1,952	46	2.4	5	.26
Maine	8	598	10	1.7	2	.33
Totals	279	21,080	319	—	53	—

[1] Final selections made after screening field selections.

a geneticist, and the surrounding standards were scored according to the criteria outlined in table 1. Based on the score obtained, together with the degree of superiority in sap sugar production that was shown, 53 final selections were made that will serve as sources of parent and clonal stock in our improvement program. These selections are being propagated vegetatively and held in a clonal bank at Burlington.

A chi-square test applied to the data showed a significant difference between states in the number of field selections that were made. An examination of the data indicated that most of the variability could be assigned to New Hampshire and Pennsylvania, where the percentages of tested trees selected were respectively the highest and lowest of the six participating states.

A low correlation found between rankings of states for percentage of field selections and for final selections made would indicate that variation between states in trees qualifying as field selections was probably due mainly to variations in the application of the selection method by the fieldmen.

During the sap season, a change was observed in the pattern of variation among trees. In a number of instances the differences between selected and standard trees in sap sugar levels gradually dropped below the level of the selection criteria. In some cases, the average sweetness of the standards exceeded those of the selected trees. Although many of the selected trees maintained their high degree of superiority throughout the season, in nearly all selection units there was a gradual reduction in selection differentials. It is conceivable that this reduction is associated with the increasing amount of sucrose, a compound sugar, that becomes hydrolized as the sap season progresses.

SUMMARY

A program for the selection of superior sugar-producing phenotypes of sugar maple was carried out in the six-state area of Maine, New Hampshire, Vermont, Massachusetts, New York and Pennsylvania.

Selection procedures were designed to minimize the effects of environmental factors and were easily understood and applied by fieldmen. The screening method provided for graduated penalties against selections. As the corresponding standard trees that were used for comparison departed from the selected tree, the latter became a less desirable candidate.

Seventy fieldmen visited 279 sugarbushes over a 4-year period, during which 21,080 trees were tested and 319 selections were made. A rigid screening applied to the selections reduced this number to 53 final trees. These trees are being propagated vegetatively by grafting at Burlington, Vermont.

The differences observed between states in the percentage of tested trees that qualified as field selections were related more to the differential application of the selection method by fieldmen in the various states than to genetic influences.

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Sawlog Weights for
APPALACHIAN HARDWOODS

by Floyd G. Timson

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

FOREWORD

THE TABLES are presented in this paper as reference material needed as a foundation for further work in the field of hardwood log weights. Such work may be undertaken by researchers, engineers, and equipment designers in the form of formal and informal studies, or by timbermen in the normal course of action to improve their operations.

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Sawlog Weights for APPALACHIAN HARDWOODS

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LOG WEIGHT instead of volume? Timberland owners, foresters, loggers, and sawmill operators have suggested a variety of ways to apply log weights instead of log-volume measurements from customary scaling procedures. Some would use log weight to estimate board-foot content. Others would apply log weights in designing log-handling machines or to determine load size on trucks. But regardless of their intentions, users will first need to know the relationships between log weight in pounds and log size and species. So we developed basic log-weight equations for the major Appalachian hardwood log species and, from these equations, constructed log-weight tables that could form the foundation for a variety of systems using log weight.

The few published sets of sawlog-weight tables for Appalachian hardwoods give estimates only for broad diameter groups of logs, not for specific log-size classes. These tables are not sufficiently detailed for many of the suggested applications. Most weight tables for a given species of logs are based on specific gravity, moisture content, and proportion of sapwood—but not on actual weights. They do not consider many other factors that influence weight, such as bark, rot, and external irregularities. Therefore our study was designed to construct weight tables based on actual log measurements and weights. And, while not directly measuring the many factors affecting weights, the results reflect the average influence of these factors.

Any practical use of weight data and detailed methods of adjusting the tables to a particular situation will be discussed in subsequent publications. The weight-predicting equations and tables are presented here as an important ingredient of procedures that should be developed if weight is to be used as a form of log measurement. The equations and tables are also for those persons who might wish to apply them to situations of personal interest involving log weights.

THE STUDY

Data Collection

The study was conducted at six mills in Maryland, West Virginia, and Virginia (fig. 1). We weighed 4,800 logs representing 15 commercially important Appalachian hardwood species. Log weights were taken at four mills during the fall season and at two other mills the following spring.

For each log, we recorded gross weight, length, diameter of small end (outside bark), and bark thickness. The weight was taken to the nearest 10 pounds, length to the nearest 1/10 of a foot, and diameter and bark thickness to the nearest 1/10 of an inch. The bark thickness was necessary to obtain scaling diameter (diameter inside bark), because all diameter measurements were taken with a diameter tape. A hydraulic load cell scale hooked in a crane line was used for weighing (fig. 2).

In collecting the field data, any woods-run log arriving at the yard was acceptable for measurement as long as it had been cut within 1 week of sampling. Since we weighed

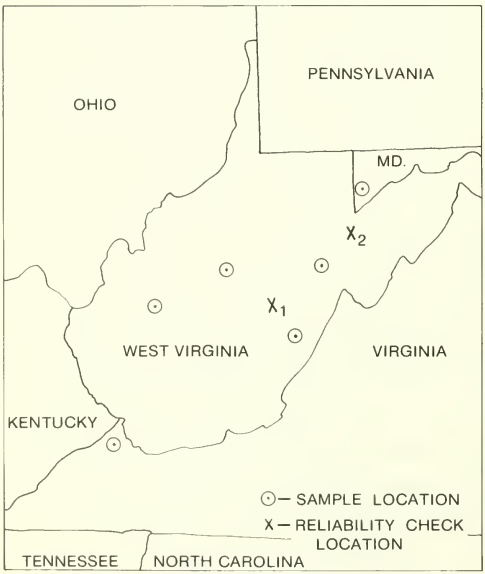


Figure 1.—Sampling area.

Figure 2.—A hydraulic load cell scale hooked in a crane line was used to weigh the logs.

logs at the mill yard, the sample included only logs acceptable to that mill.

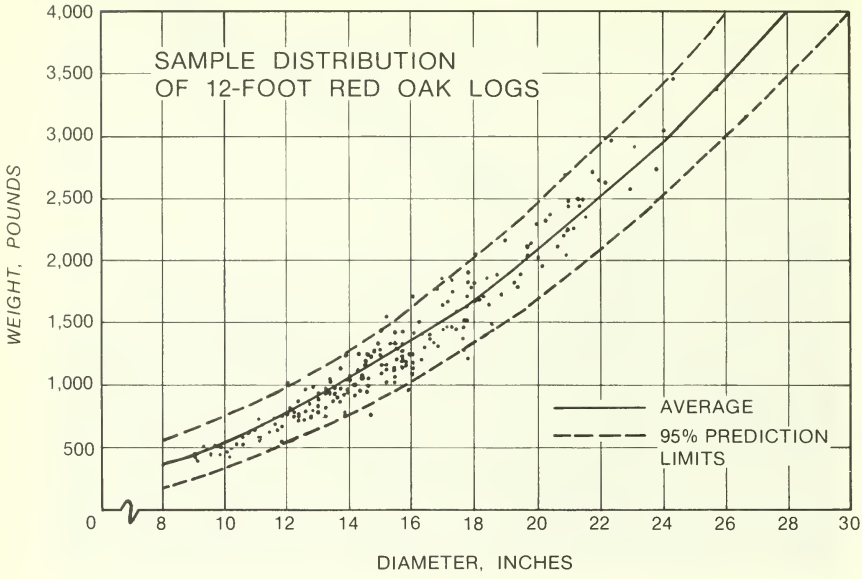
Construction of Tables

Our objective was to construct log-weight tables for each species considered. This required a prediction equation using the factors selected for measurement, which would give a reasonable and reliable predicted log-weight value based on the factor selected for measurement. To do this, regression analyses seemed adequate.

Plots of sawlog weight over the diameter by log lengths showed a slight curvilinear trend (fig. 3). The log diameter (D) and the square of the diameter times the length (D^2L) have been used successfully under similar circumstances.[1]

[1] Adams, Edward L. The development of a computer program to construct weight tables for the variable plot cruising of pulpwood. Unpublished Masters thesis on file at the School of Forestry, W. Va. Univ., Morgantown. 1969.

Figure 3.—Distribution of sample logs, average sawlog weight, and 95 percent prediction limits for 12-foot red oak logs.



Therefore, the following general model was used as a basis of our regression analysis:

$$W_i = b_o + b_1 D_i + b_2 (D_i^2 L_i) + e_i$$

where:

W_i = sawlog weight in pounds.
b_o, b_1, b_2 = population regression coefficients.
D_i = diameter inside bark at small end, in inches.
L_i = length in feet.
e_i = experimental error.

The plotted data (fig. 3) also show that the variation in log weights increase as diameter increases. This pattern suggests the use of weighted multiple regression, and based on closer examination of the data, we decided that the inverse of the square of the diameter ($1/D^2$) would be an appropriate weighting factor for our equation.

We also determined the 95-percent confidence intervals

for predictions using the weighted regressions.[2] The upper and lower limits of the intervals show, on a probability basis, the range of error of an individual prediction. A prediction limit is the two values between which a future log weight will be with probability 0.95. In the long run, the weights of all logs with the same measurements should average close to the predicted value.

From the regression equation developed for each species (table 1), we constructed the tables of weights (tables 2 to 16). The predicted average sawlog weights are tabulated by 1-inch diameter classes (inside bark, small end) from 8 to 30 inches and by 1-foot length classes from 8 to 18 feet. The

[2] Ostle, Bernard. Statistics in research. Ed. 2, 585 pp., Ames, Iowa: Iowa State Univ. Press. 1963.

Table 1.—Regression equations and the R^2 and standard error of estimate associated with each

Species	Prediction equations	R^2	Standard error of estimate
			Lbs.
h, white	$W = 66.0433 - 6.8790D + 0.3433D^2L$	0.79	9.2
sswood	$W = 125.6829 - 13.0288D + 0.3488D^2L$	.86	7.2
ech	$W = 313.2024 - 29.4343D + 0.4372D^2L$	.93	7.3
rch (yellow and black)	$W = 6.9273 + 6.5366D + 0.4086D^2L$	.85	9.8
ack gum	$W = 195.5815 - 7.8292D + 0.3826D^2L$	.82	11.1
erry, black	$W = 105.1938 - 18.2341D + 0.4081D^2L$	.92	6.3
ucumber	$W = 38.9477 - 7.7847D + 0.3534D^2L$	.88	6.4
ckory	$W = 190.1192 - 18.7348D + 0.4482D^2L$	.86	9.2
cust, black	$W = 48.7871 + 2.1538D + 0.3148D^2L$	.65	9.0
aple, red	$W = 289.0249 - 29.4911D + 0.4045D^2L$	.86	8.8
aple, sugar	$W = 191.5229 - 12.9985D + 0.3917D^2L$	.84	11.0
ak, chestnut	$W = 183.3447 - 15.9959D + 0.4516D^2L$	.85	9.0
ak, red group	$W = 169.0737 - 18.7765D + 0.4736D^2L$	.89	10.1
ak, white	$W = 224.7721 - 24.9150D + 0.4677D^2L$	.85	10.4
llow-poplar	$W = 144.0939 - 11.1559D + 0.3553D^2L$	.83	8.3

weights given under any given foot measurement are the weights of a log for that exact diameter and length measurement. For the weight of a log whose length or diameter is not on the exact foot or inch mark, the formula can be used to calculate a predicted log weight.

In tables 2 through 16, the half-widths of the 95-percent prediction intervals are given for 12-foot logs. These half-widths sometimes differ slightly from those for other length logs in the same diameter class; however, in most cases, the difference is less than 2 percent and, for all practical purposes, is negligible.

Although the prediction intervals appear quite wide, this can be attributed to the interaction of many factors, such as: site, surface irregularities (knots, burls, etc.), bark (weight can change by as much as 15 percent depending on amount of bark lost in handling), taper, location of log in tree, percent of sapwood, and decay. Density and moisture content, which in turn depend on age, dominance, position in tree, rate of growth, and location, have a great effect on weight, varying as much within a stand as between localities.

It is possible that the prediction interval could be improved by including more variables. However, R^2 values and values for the standard error of the estimates (table 1) indicate that, from a statistical standpoint, we have a satisfactory model. It is also satisfactory in a practical sense, as it is desirable to keep the input relatively simple and easy to obtain. The increased time and expense of adding other measured characteristics would not be worth the increase in precision of the answer.

The dark line in the body of each weight table encompasses weight based on 90 percent of the logs we measured. The values outside of the dark line are based on the remaining 10 percent of the field samples.

Table 2.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 66.0433 - 6.8790D + 0.3433D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	186	208	230	252	274	296	318	340	362	384	406	148
9	226	254	282	310	337	365	393	421	449	476	504	164
10	271	306	340	374	409	443	477	512	546	580	615	182
11	322	364	405	447	488	530	571	613	655	696	738	199
12	378	428	477	527	576	626	675	725	774	823	873	217
13	440	498	556	614	672	730	788	846	904	962	1,020	235
14	508	575	642	709	777	844	911	979	1,046	1,113	1,180	254
15	580	658	735	812	889	967	1,044	1,121	1,198	1,276	1,353	272
16	659	746	834	922	1,010	1,098	1,186	1,274	1,362	1,450	1,537	290
17	742	842	941	1,040	1,139	1,238	1,338	1,437	1,536	1,635	1,735	309
18	832	943	1,054	1,165	1,277	1,388	1,499	1,610	1,721	1,833	1,944	328
19	926	1,050	1,174	1,298	1,422	1,546	1,670	1,794	1,918	2,042	2,166	346
20	1,027	1,164	1,301	1,439	1,576	1,713	1,851	1,988	2,125	2,263	2,400	365
21	1,132	1,284	1,435	1,587	1,738	1,889	2,041	2,192	2,344	2,495	2,646	384
22	1,244	1,410	1,576	1,742	1,908	2,074	2,241	2,407	2,573	2,739	2,905	403
23	1,360	1,542	1,723	1,905	2,087	2,268	2,450	2,632	2,813	2,995	3,176	423
24	1,482	1,680	1,878	2,076	2,273	2,471	2,669	2,867	3,064	3,262	3,460	442
25	1,610	1,825	2,039	2,254	2,468	2,683	2,898	3,112	3,327	3,541	3,756	462
26	1,743	1,975	2,208	2,440	2,672	2,904	3,136	3,368	3,600	3,832	4,064	482
27	1,882	2,132	2,383	2,633	2,883	3,133	3,384	3,634	3,884	4,135	4,385	502
28	2,026	2,295	2,565	2,834	3,103	3,372	3,641	3,910	4,180	4,449	4,718	522
29	2,176	2,465	2,753	3,042	3,331	3,620	3,908	4,197	4,486	4,774	5,063	543
30	2,331	2,640	2,949	3,258	3,567	3,876	4,185	4,494	4,803	5,112	5,421	564

[1] Add to and subtract from weight to obtain range interval.

BASSWOOD *(Tilia spp. L.)*

Table 3.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 125.6829 - 13.0288D + 0.3488D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	200	222	244	267	289	311	334	356	378	400	423	114
9	234	262	290	319	347	375	404	432	460	488	517	127
10	274	309	344	379	414	448	483	518	553	588	623	141
11	320	362	404	446	488	531	573	615	657	699	742	155
12	371	421	471	521	572	622	672	722	773	823	873	169
13	427	486	545	604	663	722	781	840	899	958	1,017	183
14	490	558	627	695	763	832	900	968	1,037	1,105	1,173	197
15	558	636	715	793	872	950	1,029	1,107	1,186	1,264	1,343	211
16	631	720	810	899	988	1,078	1,167	1,256	1,346	1,435	1,524	226
17	710	811	912	1,013	1,113	1,214	1,315	1,416	1,517	1,618	1,718	240
18	795	908	1,021	1,134	1,247	1,360	1,473	1,586	1,699	1,812	1,925	254
19	885	1,011	1,137	1,263	1,389	1,515	1,641	1,767	1,893	2,018	2,144	269
20	981	1,120	1,260	1,400	1,539	1,679	1,818	1,958	2,097	2,237	2,376	283
21	1,082	1,236	1,390	1,544	1,698	1,851	2,005	2,159	2,313	2,467	2,621	297
22	1,189	1,358	1,527	1,696	1,865	2,033	2,202	2,371	2,540	2,709	2,878	312
23	1,302	1,486	1,671	1,855	2,040	2,224	2,409	2,594	2,778	2,963	3,147	326
24	1,420	1,621	1,822	2,023	2,224	2,425	2,626	2,826	3,027	3,228	3,429	340
25	1,544	1,762	1,980	2,198	2,416	2,634	2,852	3,070	3,288	3,506	3,724	355
26	1,673	1,909	2,145	2,380	2,616	2,852	3,088	3,324	3,559	3,795	4,031	370
27	1,808	2,062	2,316	2,571	2,825	3,079	3,334	3,588	3,842	4,097	4,351	384
28	1,948	2,222	2,495	2,769	3,042	3,316	3,589	3,863	4,136	4,410	4,683	399
29	2,094	2,388	2,681	2,974	3,268	3,561	3,855	4,148	4,441	4,735	5,028	414
30	2,246	2,560	2,874	3,188	3,502	3,816	4,130	4,444	4,758	5,072	5,386	429

[1] Add to and subtract from weight to obtain range interval.

Table 4.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 313.2024 - 29.4343D + 0.4372D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	301	329	357	385	413	441	469	497	525	553	581	122
9	331	367	402	437	473	508	544	579	614	650	685	133
10	368	412	456	499	543	587	630	674	718	762	805	146
11	412	465	518	571	624	677	730	782	835	888	941	159
12	463	526	589	652	715	778	841	904	967	1,030	1,093	173
13	521	595	669	743	817	891	964	1,038	1,112	1,186	1,260	187
14	586	672	758	843	929	1,015	1,100	1,186	1,272	1,357	1,443	201
15	658	757	855	953	1,052	1,150	1,248	1,347	1,445	1,544	1,642	216
16	737	849	961	1,073	1,185	1,297	1,409	1,521	1,633	1,744	1,856	230
17	823	949	1,076	1,202	1,329	1,455	1,581	1,708	1,834	1,960	2,087	245
18	916	1,058	1,199	1,341	1,483	1,624	1,766	1,908	2,049	2,191	2,333	259
19	1,016	1,174	1,332	1,490	1,647	1,805	1,963	2,121	2,279	2,437	2,594	274
20	1,123	1,298	1,473	1,648	1,823	1,997	2,172	2,347	2,522	2,697	2,872	288
21	1,237	1,430	1,623	1,815	2,008	2,201	2,394	2,587	2,780	2,972	3,165	303
22	1,358	1,570	1,781	1,993	2,204	2,416	2,628	2,839	3,051	3,262	3,474	318
23	1,486	1,717	1,949	2,180	2,411	2,642	2,874	3,105	3,336	3,568	3,799	332
24	1,621	1,873	2,125	2,376	2,628	2,880	3,132	3,384	3,636	3,887	4,139	347
25	1,763	2,036	2,309	2,583	2,856	3,129	3,402	3,676	3,949	4,222	4,495	362
26	1,912	2,207	2,503	2,798	3,094	3,390	3,685	3,981	4,276	4,572	4,867	377
27	2,068	2,386	2,705	3,024	3,343	3,661	3,980	4,299	4,618	4,936	5,255	392
28	2,231	2,573	2,916	3,259	3,602	3,945	4,287	4,630	4,973	5,316	5,658	407
29	2,401	2,768	3,136	3,504	3,871	4,239	4,607	4,974	5,342	5,710	6,078	422
30	2,578	2,971	3,365	3,758	4,152	4,545	4,938	5,332	5,725	6,119	6,512	437

[1] Add to and subtract from weight to obtain range interval.

BIRCH (yellow and black) *(Betula spp. L.)*

Table 5.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 6.9273 + 6.5366D + 0.4086D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	268	294	320	346	373	399	425	451	477	503	529	169
9	330	363	396	429	462	496	529	562	595	628	661	184
10	399	440	480	521	562	603	644	685	726	766	807	200
11	474	523	578	622	672	721	771	820	869	919	968	219
12	556	614	673	732	791	850	909	968	1,026	1,085	1,144	238
13	644	713	782	851	920	989	1,058	1,127	1,196	1,265	1,334	258
14	739	819	899	979	1,059	1,139	1,219	1,299	1,379	1,460	1,540	278
15	840	932	1,024	1,116	1,208	1,300	1,392	1,484	1,576	1,667	1,759	298
16	948	1,053	1,157	1,262	1,366	1,471	1,576	1,680	1,785	1,889	1,994	319
17	1,062	1,180	1,298	1,417	1,535	1,653	1,771	1,889	2,007	2,125	2,243	340
18	1,183	1,316	1,448	1,580	1,713	1,845	1,978	2,110	2,242	2,375	2,507	360
19	1,311	1,458	1,606	1,753	1,901	2,048	2,196	2,343	2,491	2,638	2,786	381
20	1,445	1,608	1,772	1,935	2,099	2,262	2,426	2,589	2,752	2,916	3,079	402
21	1,585	1,766	1,946	2,126	2,306	2,486	2,667	2,847	3,027	3,207	3,387	424
22	1,732	1,930	2,128	2,326	2,524	2,721	2,919	3,117	3,315	3,512	3,710	445
23	1,886	2,102	2,318	2,535	2,751	2,967	3,183	3,399	3,615	3,832	4,048	467
24	2,046	2,282	2,517	2,752	2,988	3,223	3,459	3,694	3,929	4,165	4,400	490
25	2,213	2,468	2,724	2,979	3,235	3,490	3,745	4,001	4,256	4,512	4,767	513
26	2,386	2,663	2,939	3,215	3,491	3,767	4,044	4,320	4,596	4,872	5,149	536
27	2,566	2,864	3,162	3,460	3,758	4,056	4,353	4,651	4,949	5,247	5,545	560
28	2,752	3,073	3,393	3,714	4,034	4,354	4,675	4,995	5,315	5,636	5,956	585
29	2,945	3,289	3,633	3,976	4,320	4,664	5,007	5,351	5,695	6,038	6,382	611
30	3,145	3,512	3,880	4,248	4,616	4,984	5,351	5,719	6,087	6,455	6,822	637

[1] Add to and subtract from weight to obtain range interval.

BLACK GUM *(Nyssa sylvatica Marsh.)*

Table 6.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 195.5815 - 7.8292D + 0.3826D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	328	353	377	402	426	451	475	500	524	549	573	197
9	373	404	435	466	497	528	558	589	620	651	682	211
10	423	461	499	538	576	614	652	691	729	767	805	227
11	479	526	572	618	665	711	757	803	850	896	942	247
12	542	597	652	707	762	817	872	928	983	1,038	1,093	268
13	611	675	740	805	869	934	999	1,063	1,128	1,193	1,257	290
14	685	760	835	910	985	1,060	1,135	1,210	1,285	1,360	1,435	313
15	766	852	939	1,025	1,111	1,197	1,283	1,369	1,455	1,541	1,627	337
16	853	951	1,049	1,147	1,245	1,343	1,441	1,539	1,637	1,735	1,833	361
17	947	1,057	1,168	1,278	1,389	1,499	1,610	1,721	1,831	1,942	2,052	385
18	1,046	1,170	1,294	1,418	1,542	1,666	1,790	1,914	2,038	2,162	2,286	409
19	1,151	1,289	1,428	1,566	1,704	1,842	1,980	2,118	2,256	2,394	2,533	433
20	1,263	1,416	1,569	1,722	1,875	2,028	2,181	2,334	2,487	2,640	2,793	457
21	1,381	1,549	1,718	1,887	2,055	2,224	2,393	2,562	2,730	2,899	3,068	481
22	1,504	1,689	1,875	2,060	2,245	2,430	2,615	2,801	2,986	3,171	3,356	505
23	1,634	1,837	2,039	2,241	2,444	2,646	2,849	3,051	3,253	3,456	3,658	529
24	1,770	1,991	2,211	2,431	2,652	2,872	3,093	3,313	3,533	3,754	3,974	554
25	1,912	2,152	2,391	2,630	2,869	3,108	3,347	3,586	3,825	4,065	4,304	578
26	2,061	2,319	2,578	2,837	3,095	3,354	3,613	3,871	4,130	4,388	4,647	602
27	2,215	2,494	2,773	3,052	3,331	3,610	3,889	4,168	4,446	4,725	5,004	627
28	2,376	2,676	2,976	3,275	3,575	3,875	4,175	4,475	4,775	5,075	5,375	652
29	2,542	2,864	3,186	3,508	3,829	4,151	4,473	4,795	5,116	5,438	5,760	677
30	2,715	3,059	3,404	3,748	4,092	4,437	4,781	5,125	5,470	5,814	6,158	703

[1] Add to and subtract from weight to obtain range interval.

CHERRY, BLACK *(Prunus serotina Ehrh.)*

Table 7.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 105.1938 - 18.2341D + 0.4081D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	168	194	220	246	272	298	324	351	377	403	429	100
9	205	238	271	304	337	370	403	436	469	503	536	112
10	249	290	330	371	412	453	494	534	575	616	657	124
11	299	349	398	447	497	546	595	645	694	744	793	136
12	356	415	474	532	591	650	709	767	826	885	944	148
13	419	488	557	626	695	764	833	902	971	1,040	1,109	161
14	489	569	649	729	809	889	969	1,049	1,129	1,209	1,289	173
15	566	658	749	841	933	1,025	1,117	1,208	1,300	1,392	1,484	186
16	649	753	858	962	1,067	1,171	1,276	1,380	1,484	1,589	1,693	198
17	738	856	974	1,092	1,210	1,328	1,446	1,564	1,682	1,800	1,918	211
18	834	966	1,099	1,231	1,363	1,495	1,628	1,760	1,892	2,024	2,156	224
19	937	1,084	1,231	1,379	1,526	1,673	1,821	1,968	2,115	2,263	2,410	236
20	1,046	1,209	1,372	1,536	1,699	1,862	2,025	2,189	2,352	2,515	2,678	249
21	1,162	1,341	1,521	1,701	1,881	2,061	2,241	2,421	2,601	2,781	2,961	262
22	1,284	1,481	1,679	1,876	2,074	2,271	2,469	2,666	2,864	3,061	3,259	275
23	1,412	1,628	1,844	2,060	2,276	2,492	2,708	2,924	3,139	3,355	3,571	288
24	1,548	1,783	2,018	2,253	2,488	2,723	2,958	3,193	3,428	3,663	3,898	301
25	1,689	1,944	2,199	2,454	2,710	2,965	3,220	3,475	3,730	3,985	4,240	314
26	1,838	2,113	2,389	2,665	2,941	3,217	3,493	3,769	4,045	4,320	4,596	327
27	1,992	2,290	2,587	2,885	3,182	3,480	3,777	4,075	4,372	4,670	4,967	340
28	2,154	2,474	2,794	3,114	3,433	3,753	4,073	4,393	4,713	5,033	5,353	354
29	2,322	2,665	3,008	3,351	3,694	4,038	4,381	4,724	5,067	5,410	5,754	367
30	2,496	2,863	3,231	3,598	3,965	4,332	4,700	5,067	5,434	5,801	6,169	381

[1] Add to and subtract from weight to obtain range interval.

Table 8.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 38.9477 - 7.7847D + 0.3534D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	157	180	202	225	248	270	293	315	338	361	383	101
9	197	226	255	283	312	341	369	398	426	455	484	113
10	243	279	314	349	385	420	455	491	526	561	597	125
11	295	338	380	423	466	509	552	594	637	680	723	137
12	352	403	454	505	556	607	658	708	759	810	861	150
13	415	475	535	594	654	714	773	833	893	953	1,012	162
14	484	553	622	691	761	830	899	969	1,038	1,107	1,176	175
15	558	637	717	796	876	955	1,035	1,114	1,194	1,274	1,353	188
16	638	728	819	909	1,000	1,090	1,181	1,271	1,362	1,452	1,542	200
17	723	825	928	1,030	1,132	1,234	1,336	1,438	1,540	1,642	1,745	213
18	814	929	1,043	1,158	1,272	1,387	1,501	1,616	1,730	1,845	1,959	226
19	911	1,039	1,166	1,294	1,422	1,549	1,677	1,804	1,932	2,059	2,187	239
20	1,014	1,155	1,296	1,438	1,579	1,721	1,862	2,003	2,145	2,286	2,427	252
21	1,122	1,278	1,434	1,589	1,745	1,901	2,057	2,213	2,369	2,525	2,680	265
22	1,236	1,407	1,578	1,749	1,920	2,091	2,262	2,433	2,604	2,775	2,946	278
23	1,355	1,542	1,729	1,916	2,103	2,290	2,477	2,664	2,851	3,038	3,225	291
24	1,480	1,684	1,887	2,091	2,294	2,498	2,702	2,905	3,109	3,312	3,516	305
25	1,611	1,832	2,053	2,274	2,495	2,715	2,936	3,157	3,378	3,599	3,820	318
26	1,747	1,986	2,225	2,464	2,703	2,942	3,181	3,420	3,659	3,898	4,136	332
27	1,889	2,147	2,405	2,662	2,920	3,178	3,435	3,693	3,951	4,208	4,466	346
28	2,037	2,314	2,591	2,868	3,145	3,423	3,700	3,977	4,254	4,531	4,808	360
29	2,191	2,488	2,785	3,082	3,379	3,677	3,974	4,271	4,568	4,866	5,163	374
30	2,350	2,668	2,986	3,304	3,622	3,940	4,258	4,576	4,894	5,212	5,530	380

[1] Add to and subtract from weight to obtain range interval.

HICKORY (*Carya spp.*)

Table 9.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 190.1192 - 18.7348D + 0.4482D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	269	298	327	355	384	413	441	470	499	527	556	147
9	311	348	384	420	457	493	529	566	602	638	674	163
10	361	406	450	495	540	585	630	675	719	764	809	181
11	417	472	526	580	634	689	743	797	851	905	960	198
12	481	546	610	675	739	804	868	933	997	1,062	1,127	216
13	552	628	704	779	855	931	1,007	1,082	1,158	1,234	1,310	234
14	630	718	806	894	982	1,069	1,157	1,245	1,333	1,421	1,509	252
15	715	816	917	1,018	1,119	1,220	1,320	1,421	1,522	1,623	1,724	270
16	808	923	1,037	1,152	1,267	1,381	1,496	1,611	1,726	1,840	1,955	289
17	907	1,037	1,166	1,296	1,426	1,555	1,685	1,814	1,944	2,073	2,203	307
18	1,014	1,159	1,305	1,450	1,595	1,740	1,885	2,031	2,176	2,321	2,466	325
19	1,128	1,290	1,452	1,613	1,775	1,937	2,099	2,261	2,422	2,584	2,746	344
20	1,249	1,428	1,608	1,787	1,966	2,146	2,325	2,504	2,683	2,863	3,042	362
21	1,377	1,575	1,773	1,970	2,168	2,366	2,563	2,761	2,959	3,156	3,354	380
22	1,513	1,730	1,947	2,164	2,381	2,598	2,815	3,031	3,248	3,465	3,682	399
23	1,656	1,893	2,130	2,367	2,604	2,841	3,078	3,315	3,552	3,789	4,027	417
24	1,805	2,063	2,322	2,580	2,838	3,096	3,354	3,612	3,871	4,129	4,387	435
25	1,962	2,242	2,523	2,803	3,083	3,363	3,643	3,923	4,203	4,483	4,764	454
26	2,126	2,429	2,732	3,035	3,338	3,641	3,944	4,247	4,550	4,853	5,156	472
27	2,298	2,624	2,951	3,278	3,605	3,931	4,258	4,585	4,912	5,238	5,565	491
28	2,476	2,828	3,179	3,530	3,882	4,233	4,585	4,936	5,287	5,639	5,990	510
29	2,662	3,039	3,416	3,793	4,170	4,547	4,923	5,300	5,677	6,054	6,431	592
30	2,855	3,258	3,661	4,065	4,468	4,872	5,275	5,678	6,082	6,485	6,889	547

[1] Add to and subtract from weight to obtain range interval.

Table 10.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 48.7871 + 2.1538D + 0.3148D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	227	247	267	287	307	327	348	368	388	408	428	145
9	272	297	323	348	374	399	425	450	476	501	527	162
10	322	353	385	416	448	479	511	542	574	605	637	180
11	377	415	453	491	529	567	605	643	681	720	758	198
12	437	482	527	573	618	663	709	754	799	845	890	216
13	502	555	608	662	715	768	821	874	928	981	1,034	235
14	572	634	696	757	819	881	942	1,004	1,066	1,127	1,189	254
15	647	718	789	860	931	1,001	1,072	1,143	1,214	1,285	1,356	273
16	728	808	889	969	1,050	1,130	1,211	1,292	1,372	1,453	1,533	293
17	813	904	995	1,086	1,177	1,268	1,359	1,450	1,541	1,632	1,723	313
18	903	1,005	1,107	1,209	1,311	1,413	1,515	1,617	1,719	1,821	1,923	333
19	998	1,112	1,226	1,339	1,453	1,567	1,680	1,794	1,908	2,021	2,135	354
20	1,099	1,225	1,351	1,477	1,603	1,728	1,854	1,980	2,106	2,232	2,358	376
21	1,204	1,343	1,482	1,621	1,760	1,898	2,037	2,176	2,315	2,454	2,593	398
22	1,315	1,467	1,619	1,772	1,924	2,077	2,229	2,381	2,534	2,686	2,838	421
23	1,430	1,597	1,763	1,930	2,096	2,263	2,429	2,596	2,763	2,929	3,096	445
24	1,551	1,732	1,913	2,095	2,276	2,457	2,639	2,820	3,001	3,183	3,364	469
25	1,676	1,873	2,070	2,267	2,463	2,660	2,857	3,054	3,250	3,447	3,644	495
26	1,807	2,020	2,233	2,445	2,658	2,871	3,084	3,297	3,509	3,722	3,935	521
27	1,943	2,172	2,402	2,631	2,861	3,090	3,320	3,549	3,779	4,008	4,238	549
28	2,083	2,330	2,577	2,824	3,070	3,317	3,564	3,811	4,058	4,305	4,551	578
29	2,229	2,494	2,758	3,023	3,288	3,553	3,818	4,082	4,347	4,612	4,877	608
30	2,380	2,663	2,946	3,230	3,513	3,796	4,080	4,363	4,646	4,930	5,213	639

[1] Add to and subtract from weight to obtain range interval.

MAPLE, RED *(Acer rubrum L.)*

Table 11.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 289.0249 - 29.4911D + 0.4045D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	260	286	311	337	363	389	415	441	467	493	519	150
9	285	318	351	384	416	449	482	515	547	580	613	163
10	317	358	398	439	479	519	560	600	641	681	722	179
11	356	405	454	502	551	600	649	698	747	796	845	195
12	401	459	517	575	634	692	750	808	867	925	983	212
13	452	520	589	657	725	794	862	931	999	1,067	1,136	229
14	510	589	668	748	827	906	986	1,065	1,144	1,223	1,303	247
15	574	665	756	847	938	1,029	1,120	1,211	1,302	1,393	1,484	265
16	645	749	852	956	1,059	1,163	1,266	1,370	1,473	1,577	1,681	283
17	722	839	956	1,073	1,190	1,307	1,424	1,541	1,658	1,774	1,891	302
18	806	937	1,068	1,199	1,330	1,461	1,592	1,723	1,855	1,986	2,117	320
19	896	1,042	1,188	1,334	1,480	1,626	1,772	1,918	2,065	2,211	2,357	338
20	993	1,155	1,317	1,478	1,640	1,802	1,964	2,126	2,287	2,449	2,611	356
21	1,096	1,275	1,453	1,631	1,810	1,988	2,167	2,345	2,523	2,702	2,880	375
22	1,206	1,402	1,597	1,793	1,989	2,185	2,381	2,576	2,772	2,968	3,164	393
23	1,322	1,536	1,750	1,964	2,178	2,392	2,606	2,820	3,034	3,248	3,462	412
24	1,445	1,678	1,911	2,144	2,377	2,610	2,843	3,075	3,308	3,541	3,774	431
25	1,574	1,826	2,079	2,332	2,585	2,838	3,090	3,343	3,596	3,849	4,102	450
26	1,709	1,983	2,256	2,530	2,803	3,076	3,350	3,623	3,897	4,170	4,444	470
27	1,851	2,146	2,441	2,736	3,031	3,326	3,620	3,915	4,210	4,505	4,800	489
28	2,000	2,317	2,634	2,951	3,268	3,585	3,902	4,220	4,537	4,854	5,171	509
29	2,155	2,495	2,835	3,175	3,515	3,856	4,196	4,536	4,876	5,216	5,556	530
30	2,316	2,680	3,044	3,408	3,772	4,136	4,500	4,864	5,228	5,592	5,956	551

Table 12.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 191.5229 - 12.9985D + 0.3917D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	288	313	338	363	388	413	438	463	488	513	538	177
9	328	360	391	423	455	487	518	550	582	613	645	196
10	374	414	453	492	531	570	609	649	688	727	766	217
11	427	475	522	569	617	664	712	759	806	854	901	238
12	486	543	599	656	712	768	825	881	938	994	1,050	259
13	552	618	684	750	816	883	949	1,015	1,081	1,147	1,214	280
14	623	700	777	854	930	1,007	1,084	1,161	1,237	1,314	1,391	302
15	701	789	877	966	1,054	1,142	1,230	1,318	1,406	1,494	1,582	323
16	785	886	986	1,086	1,186	1,287	1,387	1,487	1,588	1,688	1,788	345
17	876	989	1,102	1,215	1,329	1,442	1,555	1,668	1,781	1,895	2,008	367
18	972	1,099	1,226	1,353	1,480	1,607	1,734	1,861	1,988	2,115	2,242	388
19	1,075	1,217	1,358	1,500	1,641	1,782	1,924	2,065	2,207	2,348	2,489	410
20	1,185	1,341	1,498	1,655	1,811	1,968	2,125	2,281	2,438	2,595	2,751	432
21	1,300	1,473	1,646	1,818	1,991	2,164	2,337	2,509	2,682	2,855	3,028	454
22	1,422	1,611	1,801	1,991	2,180	2,370	2,559	2,749	2,939	3,128	3,318	475
23	1,550	1,757	1,964	2,171	2,379	2,586	2,793	3,000	3,208	3,415	3,622	497
24	1,684	1,910	2,135	2,361	2,587	2,812	3,038	3,263	3,489	3,715	3,940	519
25	1,825	2,069	2,314	2,559	2,804	3,049	3,294	3,538	3,783	4,028	4,273	541
26	1,971	2,236	2,501	2,766	3,031	3,295	3,560	3,825	4,090	4,355	4,619	563
27	2,125	2,410	2,696	2,981	3,267	3,552	3,838	4,123	4,409	4,695	4,980	586
28	2,284	2,591	2,898	3,205	3,512	3,819	4,127	4,434	4,741	5,048	5,355	608
29	2,450	2,779	3,108	3,438	3,767	4,097	4,426	4,756	5,085	5,414	5,744	630
30	2,621	2,974	3,327	3,679	4,032	4,384	4,737	5,089	5,442	5,794	6,147	653

[1] Add to and subtract from weight to obtain range interval.

OAK, CHESTNUT *(Quercus prinus L.)*

Table 13.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 183.3447 - 15.9959D + 0.4516D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	286	315	344	373	402	431	460	488	517	546	575	143
9	332	368	405	441	478	514	551	588	624	661	697	160
10	384	429	474	520	565	610	655	700	745	791	836	177
11	444	499	553	608	663	717	772	827	881	936	990	194
12	511	576	641	706	771	836	901	966	1,031	1,096	1,161	211
13	585	662	738	814	891	967	1,043	1,120	1,196	1,272	1,349	229
14	667	756	844	933	1,021	1,110	1,198	1,287	1,375	1,464	1,552	246
15	756	857	959	1,061	1,162	1,264	1,365	1,467	1,569	1,670	1,772	264
16	852	967	1,083	1,199	1,314	1,430	1,545	1,661	1,777	1,892	2,008	282
17	955	1,085	1,216	1,347	1,477	1,608	1,738	1,869	1,999	2,130	2,260	299
18	1,065	1,212	1,358	1,504	1,651	1,797	1,943	2,090	2,236	2,382	2,529	317
19	1,183	1,346	1,509	1,672	1,835	1,998	2,161	2,324	2,487	2,650	2,813	335
20	1,308	1,489	1,669	1,850	2,031	2,211	2,392	2,572	2,753	2,934	3,114	353
21	1,440	1,639	1,838	2,038	2,237	2,436	2,635	2,834	3,033	3,233	3,432	371
22	1,579	1,798	2,017	2,235	2,454	2,672	2,891	3,109	3,328	3,547	3,765	389
23	1,726	1,965	2,204	2,443	2,682	2,921	3,159	3,398	3,637	3,876	4,115	408
24	1,880	2,140	2,400	2,660	2,920	3,180	3,441	3,701	3,961	4,221	4,481	426
25	2,041	2,323	2,605	2,888	3,170	3,452	3,734	4,017	4,299	4,581	4,863	444
26	2,209	2,514	2,820	3,125	3,430	3,736	4,041	4,346	4,651	4,957	5,262	463
27	2,385	2,714	3,043	3,372	3,701	4,031	4,360	4,689	5,018	5,348	5,677	482
28	2,567	2,921	3,275	3,629	3,984	4,338	4,692	5,046	5,400	5,754	6,108	500
29	2,757	3,137	3,517	3,897	4,276	4,656	5,036	5,416	5,796	6,175	6,555	519
30	2,954	3,361	3,767	4,174	4,580	4,987	5,393	5,799	6,206	6,612	7,019	539

OAK, RED (*Quercus spp.*)

Table 14.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 169.0737 - 18.7765D + 0.4736D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	261	291	321	352	382	412	443	473	503	534	564	159
9	306	345	383	422	460	498	537	575	613	652	690	178
10	360	407	454	502	549	596	644	691	739	786	833	198
11	420	478	535	592	650	707	764	822	879	936	994	218
12	489	557	625	693	762	830	898	966	1,034	1,103	1,171	237
13	565	645	725	805	885	965	1,045	1,125	1,205	1,285	1,365	257
14	648	741	834	927	1,020	1,112	1,205	1,298	1,391	1,484	1,577	277
15	739	846	952	1,059	1,166	1,272	1,379	1,485	1,592	1,698	1,805	297
16	838	959	1,081	1,202	1,323	1,444	1,565	1,687	1,808	1,929	2,050	316
17	944	1,081	1,218	1,355	1,492	1,629	1,766	1,902	2,039	2,176	2,313	336
18	1,058	1,212	1,365	1,518	1,672	1,825	1,979	2,132	2,286	2,439	2,593	356
19	1,180	1,351	1,521	1,692	1,863	2,034	2,205	2,376	2,547	2,718	2,889	376
20	1,309	1,498	1,687	1,877	2,066	2,256	2,445	2,635	2,824	3,013	3,203	396
21	1,445	1,654	1,863	2,072	2,280	2,489	2,698	2,907	3,116	3,325	3,534	416
22	1,589	1,818	2,048	2,277	2,506	2,735	2,965	3,194	3,423	3,652	3,881	436
23	1,741	1,991	2,242	2,493	2,743	2,994	3,244	3,495	3,745	3,996	4,246	456
24	1,900	2,173	2,446	2,719	2,991	3,264	3,537	3,810	4,083	4,355	4,628	475
25	2,067	2,363	2,659	2,955	3,251	3,547	3,843	4,139	4,435	4,731	5,027	495
26	2,242	2,562	2,882	3,202	3,522	3,842	4,162	4,483	4,803	5,123	5,443	515
27	2,424	2,769	3,114	3,459	3,805	4,150	4,495	4,840	5,186	5,531	5,876	535
28	2,613	2,984	3,356	3,727	4,098	4,470	4,841	5,212	5,584	5,955	6,326	555
29	2,810	3,209	3,607	4,005	4,403	4,802	5,200	5,598	5,997	6,395	6,793	575
30	3,015	3,441	3,868	4,294	4,720	5,146	5,572	5,999	6,425	6,851	7,277	595

[1] Add to and subtract from weight to obtain range interval.

OAK, WHITE (*Quercus spp.*)

Table 15.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 224.7721 - 24.9150D + 0.4677D^2L$]

Scaling diameter	Log length (feet)											Half-width of 95% confidence interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	264	294	324	354	384	414	444	474	504	534	564	170
9	303	341	379	417	455	493	530	568	606	644	682	187
10	349	396	443	490	536	583	630	677	723	770	817	206
11	403	460	516	573	629	686	743	799	856	912	969	225
12	464	531	599	666	734	801	868	936	1,003	1,070	1,138	245
13	533	612	691	770	849	928	1,007	1,086	1,165	1,244	1,323	265
14	609	701	792	884	976	1,067	1,159	1,251	1,342	1,434	1,526	286
15	692	798	903	1,008	1,113	1,219	1,324	1,429	1,534	1,640	1,745	306
16	784	903	1,023	1,143	1,262	1,382	1,502	1,622	1,741	1,861	1,981	327
17	882	1,017	1,152	1,288	1,423	1,558	1,693	1,828	1,963	2,099	2,234	348
18	988	1,140	1,291	1,443	1,594	1,746	1,897	2,049	2,200	2,352	2,504	368
19	1,102	1,270	1,439	1,608	1,777	1,946	2,115	2,284	2,452	2,621	2,790	389
20	1,223	1,410	1,597	1,784	1,971	2,158	2,345	2,532	2,719	2,906	3,094	410
21	1,351	1,557	1,764	1,970	2,176	2,382	2,589	2,795	3,001	3,208	3,414	431
22	1,487	1,714	1,940	2,166	2,393	2,619	2,845	3,072	3,298	3,524	3,751	452
23	1,631	1,878	2,125	2,373	2,620	2,868	3,115	3,363	3,610	3,857	4,105	473
24	1,782	2,051	2,320	2,590	2,859	3,129	3,398	3,667	3,937	4,206	4,476	494
25	1,940	2,232	2,525	2,817	3,109	3,402	3,694	3,986	4,279	4,571	4,863	516
26	2,106	2,422	2,738	3,054	3,371	3,687	4,003	4,319	4,635	4,951	5,268	537
27	2,279	2,620	2,961	3,302	3,643	3,984	4,325	4,666	5,007	5,348	5,689	559
28	2,460	2,827	3,194	3,560	3,927	4,294	4,660	5,027	5,394	5,760	6,127	581
29	2,649	3,042	3,435	3,829	4,222	4,615	5,009	5,402	5,795	6,189	6,582	603
30	2,844	3,265	3,686	4,107	4,528	4,949	5,370	5,791	6,212	6,633	7,054	625

[1] Add to and subtract from weight to obtain range interval

Table 16.—Estimated weight of logs with bark by length and diameter inside bark, small end

[Table based on $W = 144.0939 - 11.1559D + 0.3553D^2L$]

Scaling diameter	Log length (feet)											Half-width confidence of 95% interval[1]
	8	9	10	11	12	13	14	15	16	17	18	
In.	*Sawlog weight, lbs.*											*Lbs.*
8	236	259	282	304	327	350	373	395	418	441	464	131
9	273	302	331	360	389	417	446	475	504	532	561	147
10	316	352	387	423	458	494	529	565	601	636	672	163
11	365	408	451	494	537	580	623	666	709	752	795	179
12	419	470	521	573	624	675	726	777	828	880	931	195
13	479	539	599	659	719	779	839	899	959	1,019	1,079	211
14	545	614	684	753	823	893	962	1,032	1,102	1,171	1,241	228
15	616	696	776	856	936	1,016	1,096	1,175	1,255	1,335	1,415	244
16	693	784	875	966	1,057	1,148	1,239	1,330	1,421	1,511	1,602	261
17	775	878	981	1,084	1,186	1,289	1,392	1,494	1,597	1,700	1,802	277
18	864	979	1,094	1,209	1,324	1,439	1,555	1,670	1,785	1,900	2,015	294
19	958	1,086	1,214	1,343	1,471	1,599	1,727	1,856	1,984	2,112	2,241	310
20	1,058	1,200	1,342	1,484	1,626	1,768	1,910	2,052	2,195	2,337	2,479	327
21	1,163	1,320	1,476	1,633	1,790	1,946	2,103	2,260	2,417	2,573	2,730	343
22	1,274	1,446	1,618	1,790	1,962	2,134	2,306	2,478	2,650	2,822	2,994	360
23	1,391	1,579	1,767	1,955	2,143	2,331	2,519	2,707	2,895	3,082	3,270	376
24	1,513	1,718	1,923	2,127	2,332	2,537	2,741	2,946	3,151	3,355	3,560	393
25	1,641	1,863	2,085	2,308	2,530	2,752	2,974	3,196	3,418	3,640	3,862	409
26	1,775	2,015	2,256	2,496	2,736	2,976	3,216	3,457	3,697	3,937	4,177	426
27	1,915	2,174	2,433	2,692	2,951	3,210	3,469	3,728	3,987	4,246	4,505	443
28	2,060	2,338	2,617	2,896	3,174	3,453	3,731	4,010	4,288	4,567	4,846	460
29	2,211	2,510	2,808	3,107	3,406	3,705	4,004	4,303	4,601	4,900	5,199	477
30	2,367	2,687	3,007	3,327	3,646	3,966	4,286	4,060	4,926	5,245	5,565	493

[1] Add to and subtract from weight to obtain range interval.

RELIABILITY OF TABLES

To check the reliability of the tables, we made a test at three mills not sampled during the data gathering phase. Two mills were in the original sampling region (fig. 1), and the third was in north-central New York.

The test had two objectives: the first was to see if 95 percent of the logs weighed would fall within the range of weight values predicted in the tables (table 17, appendix). At the three mills, we weighed 3,468 logs; 95.53 percent of the logs fell within the limits given in the tables.

The second objective was to check the reliability of a table predicting log weight in a given situation. (See appendix for test procedure.) At the test site in east-central West Virginia, seven tables were checked—white ash, basswood, beech, hickory, sugar maple, red oak, and yellow-poplar. Beech and yellow-poplar were not significantly different at the 5-percent level from the tables as published (appendix, table 18).

In northeastern West Virginia, seven species—beech, black cherry, red maple, sugar maple, chestnut oak, red oak, and yellow-poplar—were checked. Three species—beech, red maple, and sugar maple—were not significantly different from the tables as published (appendix, table 19).

At the test site in north-central New York, three tables were checked—beech, birch, and sugar maple—and all were found to differ significantly from the tables (appendix, table 20).

The results were not unexpected. Because of all the factors that affect weight, it would not be unusual to have to adjust weight tables to fit actual conditions in a given situation.

DISCUSSION

Two logs of the same size and species will often differ greatly in weight. This was revealed by the study and is shown by the prediction interval. It was this variation that we wanted our confidence intervals to reflect; therefore the tabular values are based on mill-run logs, and no compensation was made for any factor that could affect log weight.

The tables give the weight one might expect for a log of a given size and species. Also, by use of the value in the half-width column, the range in pounds that will include 95 logs out of 100 can be computed.

If the tables are to be used to predict the weight of logs in a situation other than that under which they were constructed, then the tables should be tested for that particular situation; for instance, logs from a given site. The test we used in making reliability checks on these tables is an acceptable method (appendix).

As our check revealed, it may be necessary to use an adjustment factor to bring predicted weight in line with observed weights. Studies are now under way to design methods of computing an adjustment factor so that a table, or results obtained from tables, may be adjusted to the accuracy needed for a particular procedure such as weight scaling.

As of now, we will only suggest that the predicted weight (preferably group weight) be adjusted by the percent mean difference obtained as a result of conducting the reliability check as described in the appendix.

APPENDIX

Table 17.—Percent of logs tested that fell within 95 percent prediction interval

Location	Species	Total no. of logs	% within prediction interval
East-central West Virginia (X_1, Fig. 1)	Red maple	15	100.00
	Sugar maple	105	96.19
	Birch	96	95.83
	Hickory	80	96.25
	Beech	130	93.08
	White ash	137	97.08
	Yellow-poplar	414	91.06
	Red Oak	140	97.14
	Basswood	214	96.26
	ALL	1,331	94.51
Northeast West Virginia (X_2, Fig. 1)	Red maple	117	100.00
	Sugar maple	98	97.96
	Beech	61	95.08
	Yellow-poplar	252	94.44
	Black cherry	113	92.92
	Chestnut oak	93	93.55
	Red oak	171	96.49
	Basswood	48	95.83
	ALL	953	95.59
North-central New York	Birch	331	96.07
	Sugar maple	600	97.17
	Beech	253	95.65
	ALL	1,184	96.54
All locations	Red maple	132	100.00
	Sugar maple	803	97.14
	Birch	427	96.02
	Hickory	80	96.25
	Beech	444	94.82
	White ash	137	97.08
	Yellow-poplar	666	92.34
	Black cherry	113	92.92
	Chestnut oak	93	93.55
	Red oak	311	96.78
	Basswood	262	96.18
	ALL	3,468	95.53

Reliability Test of Tables

The weight tables must be checked to determine their reliability when applied to logs weighed in specific situations and in other localities and seasons.

The procedure used for evaluating weight table reliability is outlined below. This method first compares the difference in weight between the actual log in the check sample and the estimated weight shown for a similar log in the table. The difference between the actual and estimated weight is noted for each, and the differences are totaled and averaged to find the percent mean difference.

At this point, the user might be tempted to adjust his tables by the percent mean difference to get a more accurate measure of the grouped weight of logs sampled in his area. However, he has no assurance that the logs in his first sample represent the weight variation found for the whole stand or locality. Therefore, he must use the procedures outlined below to delineate this variation in terms of confidence limits. When he has done this, he can then determine the number of *additional* check samples needed to give him the measure of log weight variation and reliability that he needs to make for proper table adjustment.

In the outline below, steps 3b through 7, show how to calculate the number of logs needed to make one confident that the calculated percent mean difference is reasonably close to the true percent mean difference (the percent difference between actual and predicted weight of all the logs whose weights are to be predicted if the difference was calculated based on knowing the actual weight and measurement of each log). Steps 8 and 9 are instructions on when to adjust the table if all steps are followed.

For the purpose of the test conducted for this paper, we used a $\pm$ 2 percent interval or less at the 95 percent confidence level. This means we are 95 percent sure that the true percent mean difference lies somewhere within the range of $\pm$ 2 percent or less (based on table weight) of the percent mean difference found for the logs sampled. For example: if we found the percent mean difference for the logs sampled to be 4.5 percent, we could be confident that 95 percent of the time the true percent mean difference would be somewhere in the range of 2.5 percent to 6.5 percent.

The person using this test has to make one decision before he calculates the number of logs needed to give some confidence to the percent mean difference for the logs he samples. The decision is the degree of accuracy he desires to place in the test. In step 4, this is called *desired half-width* —the half-width being the value (percent in this case) one adds to and subtracts from the calculated mean difference to obtain the range in which the true mean difference lies.

Test Procedure

(Conduct for Each Table)

1. Weigh and measure (scaling diameter and length) a sample of $n = 60$ logs.

2. Find percent difference (d_i) between the actual weight (AW) and predicted weight (PW) for each log:

$$d_i = [(PW - AW)/AW] \times 100$$

3. Calculate the following for the sample of 60 logs:
   a. Percent mean difference ($\overline{D}$) for sample

$$\overline{D} = \sum_{i=1}^{n} d_i/n \text{ or } (d_1 + d_2 + d_3 + \text{----- } d_n)/n$$

   b. Standard deviation (S) for sample

$$S = \sqrt{[\Sigma d_i^2 - (\Sigma d_i)^2/n]/(n-1)}$$

   c. The half width of 95 percent confidence interval (CW) for the sample

$$CW = t_{0.05,n} \left(S/\sqrt{n}\right)$$

$$\text{where } t_{0.05,n} = 2.00 \text{ (for } n = 60 \text{ logs)}$$

4. If (CW) is smaller than the *desired* half-width (W) of the confidence interval, the sample size is adequate and no more logs need be measured. (Go to step 8 if $CW \leq W$).

5. If (CW) is larger than the *desired* half-width (W) of the confidence interval, take another sample such that the total logs measured and weighed are equal to or larger than (N).

$$N = 2.00\ S/W$$

   Note: If $W = 2.00$, then N should be one more than the rounded value of S.

6. Weigh and measure the additional logs needed to give desired W. Additional logs needed = Total logs required (N) — logs originally weighed (n or 60).

7. Calculate new percent mean difference ($\overline{D}$) based on the whole sample:

$$\overline{D} = \sum_{i=1}^{N} d_i/N \text{ or } (d_1 + d_2 + d_3 + \text{----- } d_n)/N$$

[It is shown in Cochran (1953:59), that:

Probability (Pr) $(|\bar{D} - \Delta| \geq W) \leq 0.05$

where Δ is the true percent difference. The confidence statement can also be written as:

$\Pr(\bar{D} - W \leq \Delta \leq \bar{D} + W) \geq 0.95$

In other words, $\bar{D} \pm W$ is the 95 percent confidence interval for the bias in the tables.

The confidence statements are based on the assumption that the percent differences are normally distributed. Also, we have taken the view that the table values are fixed instead of random variables.][3]

8. If $\bar{D}$ is equal to or less than W, the table weights are suitable to use as published for the situation in which they were tested.

9. If $\bar{D}$ is greater than W, then some adjustment is needed if table weights are put to use in the situation for which tables are tested.

Adjustment of Tables

For now, if the test shows some adjustment of table is needed, you should use $\bar{D}$ as value of adjustment factor. Individual log weight in the table should not be adjusted, but the adjustment should be applied to total predicted weight obtained from the sum of the individual log weights. This total weight should be adjusted by the factor $1 - \bar{D}/100$.

Example: The red oak table is tested in a given situation where $\bar{D} = +4.5$ percent with a 2 percent half-width of the confidence interval (W). Since $\bar{D} > W$, some adjustment is necessary. The weight of each log in the group is predicted and the values are totaled. Suppose the total predicted weight was 45,000 pounds. This weight should be multiplied by the factor $(1 - \bar{D}/100)$. In this case, $(1 - (+4.5)/100)$ gives $45{,}000 \times .955$ which equals 42,975 pounds adjusted predicted weight.

So for future samples drawn from the same population, the user should adjust his estimated tabular red oak values by 4.5 percent. Since the check sample shows the table value to overestimate, the adjustment would be to reduce estimated tabular values.

[3] Cochran, W. G. Sampling techniques. 322 pp. John Wiley and Sons, N.Y. 1953.

Table 18.—Check of Appalachian sawlog predicted weights in east-central West Virginia

Species	No. logs in sample	Percent mean difference per log	Half-width of 95% confidence interval
White ash	137	[1]—7.09	1.74
Basswood	214	2.29	1.81
Beech	130	—1.97	1.98
Hickory	80	—3.14	1.97
Sugar maple	105	—3.45	2.00
Red oak	140	—2.09	1.77
Yellow-poplar	417	.79	1.41

[1] (—) Minus indicates estimated weight less than actual weight.

Table 19.—Check of Appalachian sawlog predicted weights in northeastern West Virginia

Species	No logs in sample	Percent mean difference per log	Half-width of 95% confidence interval
Beech	61	2.27	[1]2.43
Black cherry	112	[2]—3.13	2.05
Red maple	117	.76	2.03
Sugar maple	99	—.87	2.07
Chestnut oak	93	—3.76	2.01
Red oak	171	—2.70	1.55
Yellow-poplar	252	6.83	1.87

[1] Required number of logs not available at time of test to reduce interval to 2 percent.
[2] (—) Minus indicates estimated weight less than actual weight.

Table 20.—Check of Appalachian sawlog predicted weights in north-central New York

Species	No logs in sample	Percent mean difference per log	Half-width of 95% confidence interval
Beech	260	12.33	2.05
Birch (yellow)	331	9.36	1.39
Sugar maple	600	1.52	1.06

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Reproduction 7 Years After SEED-TREE HARVEST CUTTING in Appalachian Hardwoods

by G. R. Trimble, Jr.

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Introduction

THIS IS A REPORT on the potential of young even-aged hardwood stands, based on measurements made when the stands were 7 years old. It was designed to provide forest managers with data that can aid them in deciding whether or not to do early cultural work. As a basis for this appraisal, we determined for the stands: (1) the number, size, and distribution of stems; (2) the species composition; (3) the stem quality; and (4) the effect of early cultural treatments.

Because we stratified our results by site-quality classes, we believe that these results should be generally applicable to hardwood forests in the central Appalachians. We recognize that our evaluation, made on stands this young, can only indicate and not blueprint development. However, the need for specific information about the results of regeneration cuttings in even-aged silviculture is so great that the outcome should be useful now.

This paper is a sequel to a previous publication that described reproduction on the same areas when the new stands were only 3 years old (*Wendel and Trimble 1968*).

Study Areas and Methods

The study was carried out on nine compartments that averaged about 12 acres each. Three of the compartments were on areas of site index 80, three on site index 70, and three on site index 60—based on 10-foot oak site-index classes (*Schnur 1937*). These indexes characterize sites that will be referred to as excellent, good, and fair.

The soils of the study area are of medium texture, well drained, probably average over 3 feet deep, and are derived mostly from sandstone and shale (with some limestone influence in places). The general area gets about 58 inches of well-distributed rainfall a year; the frost-free growing season is about 4½ months long.

The original stands were well stocked; they had not been disturbed by cutting or fire for at least 35 years. All of them contained considerable sawtimber volume. The most numerous species among sawtimber stems were hickories, sugar maple, red oak, white oak, and black cherry on the excellent sites; yellow-poplar, red oak, hickories, chestnut oak, and white oak on the good sites; and chestnut oak, red oak, black gum, and white oak on the fair sites. (Scientific names of species are given in the Appendix).

Most of the sawtimber trees on the three excellent-site areas and many on one good-site area and one fair-site area were old-growth trees 90 to 100 years old. The sawtimber trees on the other areas were mostly second growth, 55 to 60 years old, with a few old-growth residuals.

The same harvest-cutting procedure was used on all study areas: in the first cutting, all stems over 5 inches d.b.h. were logged except for designated seed trees. After three growing seasons, the seed trees were removed.

The number of seed trees varied by site quality. We reasoned that, on the lower site-quality areas, more seed trees were needed to obtain adequate distribution of seeds because of the greater proportion of the heavy-seeded oaks. By site-index class, we left the following numbers of seed trees per

Table 1.—Cultural treatments

Compartment	Oak site index	Seed trees	Treatment of residual 1-5 inch d.b.h. stems	Crop-tree release
No.	*Feet*	*No.*		
32	80	10	—	√
33	80	10	—	—
43	80	10	√	√
36	70	20	√	√
37	70	20	—	—
39	70	20	—	√
34	60	30	—	√
35	60	30	—	—
38	60	30	√	√

acre: site index 80—10 trees, site index 70—20 trees, and site index 6—30 trees (table 1).

Two types of precommercial cultural operations were made in the new stands of reproduction (table 1). On three of the compartments—43, 36, and 38—the residual 1- to 5-inch stems still living after the seed-tree cutting were treated (in 43 they were cut; in 36 and 38 they were basal-sprayed). On six compartments, crop-tree releases were made at 7 to 9 years—compartments 43, 36, and 38 (this was the second cultural treatment for these three compartments); and compartments 32, 39, and 34 (this was the first cultural treatment on these compartments). And on three of the compartments—33, 37, and 35—no cultural work at all was done.

To measure the development of the new stand, we sampled reproduction at frequent intervals, beginning before the harvest cuttings. Tallies were made by species, size class, stem origin (seedlings or sprouts), and for the larger stems by stem quality class—good or poor. The seedling category included seedling sprouts, defined as stems arising from stumps less than 2 inches in diameter at ground line.

Two size classes of reproduction were recognized: *Small* (1 foot high to 1 inch d.b.h.) and *large* (1 inch to 5 inches d.b.h.). Small reproduction was sampled on milacre plots and

large reproduction on 1/100-acre plots. Both size classes of reproduction were tallied as seedlings or stump sprouts, and the large reproduction was also tallied as good or poor stems.

All reproduction tallies after the harvest cutting were made at 45 permenent sampling points in a 5-acre area in the center of each compartment.

Results

ABUNDANCE OF COMMERCIAL SPECIES

Only stems of commercial species were tallied. A commercial species is one that is merchantable in the area for any product: veneer, sawtimber, ties, posts, blocking, pallet stock, pulpwood, etc.

The number of *small stems* per acre at 7 years averaged 10,741 for the excellent site, 5,985 for the good site, and 8,181 for the fair sites (table 2). There were appreciably fewer stems of this size class than occupied the same areas 4 years earlier: 13,338 for the excellent site, 10,183 for the good sites, and 13,604 for the fair sites.

The number of *large stems* per acre at 7 years (excluding those residuals that were between 1 and 5 inches d.b.h. at the time the overstories were harvested) averaged 362 for the excellent sites, 874 for the good sites, and 774 for the fair sites (table 2). Four years earlier, only a small number of stems had reached this size.

Three factors may be partially responsible for the fewer large stems on the excellent sites: (1) two of the excellent-site areas were characterized by an unusually heavy ground cover of herbaceous vegetation that obviously slowed seedling growth (fig. 1); (2) all three excellent-site stands were older than most of the stands on the sites of lower quality, and thus stump sprouts (which are faster growing than young seedlings) were fewer; and (3) the original stands on the lower-quality sites had many more red maple, a species that stump sprouts prolifically (fig. 2).

Table 2.—Reproduction of commercial species after 7 growing seasons

Compartment number	Small reproduction				Large reproduction			
	Total stems/acre	Sprout stems/acre	Proportion of sprouts	Proportion of $^{1}/_{1000}$-acre plots stocked	Total stems/acre	Sprout stems/acre	Proportion of sprouts	Proportion of $^{1}/_{100}$-acre plots stocked
	No.	*No.*	*Pct.*	*Pct.*	*No.*	*No.*	*Pct.*	*Pct.*
				EXCELLENT SITE				
32	7,400	666	9	96	420	248	59	80
33	15,755	1,444	9	98	378	208	55	84
43	9,067	1,289	14	93	289	150	52	91
Ave.	10,741	1,133	11	96	362	202	56	85
				GOOD SITE				
36	6,223	1,533	25	91	926	630	68	96
37	4,333	1,133	26	91	790	450	57	100
39	7,400	1,444	20	96	907	526	58	100
Ave.	5,985	1,370	23	93	874	535	61	99
				FAIR SITE				
34	8,955	1,644	18	98	579	446	77	89
35	8,156	1,756	22	96	898	521	58	100
38	7,434	1,886	25	98	844	675	80	100
Ave.	8,181	1,762	22	97	774	547	71	96

Figure 1.—Heavy herbaceous ground cover on an excellent site.

Figure 2.—A clump of red maple stump sprouts.

As was to be expected, the total number of reproduction stems decreased as the new stand increased in age from 3 to 7 years. Mortality among small stems were high, and replacement from below was slight because, after 3 years, the ground was densely shaded.

DISTRIBUTION OF COMMERCIAL SPECIES

The percentages of sampled milacres that were stocked with at least one *small stem* of a commercial species were: excellent sites, 96 percent; good sites, 93 percent; and fair sites, 97 percent. Little difference in stocking existed either within or between site-quality classes (table 2). The stocking percentages at 7 years were almost identical to what they had been at 3 years.

The percentages of 1/100-acre plots that were stocked with at least one *large stem* of a commercial timber species were: excellent site, 85; good site, 99; and fair site, 96 (table 2).

SPECIES COMPOSITION

By sites, for *small stems,* the five leading species at 7 years did not differ much in ranking from the five leaders at 3 years. The first five at 7 years were:

Excellent site: (1) Sweet birch, (2) sugar maple, (3) yellow-poplar, (4) white ash, and (5) black cherry.

Good site: (1) Sugar maple, (2) yellow-poplar, (3) sassafras, (4) sweet birch, (5) red maple.

Fair site: (1) Sassafras, (2) sweet birch, (3) red maple, (4) chestnut oak, (5) red oak.

On all the areas, we found a large number of species. The three compartments on the excellent site had 13, 14, and 15 different commercial species; on the good site, the numbers of species were 13, 17, and 18; and on the fair site, they were 12, 13, and 14.

As was expected, site quality had a strong influence on species composition. Yellow-poplar, black cherry, and sugar maple were more abundant on the excellent sites; sassafras, red maple, and the oaks were more numerous on the fair sites. The good site was the transition zone for species composition and, perhaps for this reason, had a greater number of species than either the excellent or the fair sites. As we have noted, stems of sweet birch were numerous on all three sites. Sweet birch appears to be unusually tolerant of site quality differences. Moreover, because of its early fast growth rate, it gets a jump on many species that outgrow it later.

For *large stems* of commercial species, the five most numerous were (numbers in parenthesis are numbers of stems per acre):

Ranking	*Excellent sites*	*Good sites*	*Fair sites*
1	Sugar maple (91)	Black locust (124)	Red maple (186)
2	Basswood (49)	Sugar maple (111)	Sassafras (176)
3	Eastern hophornbeam (43)	Red maple (107)	Chestnut oak (103)
4	Black locust (38)	Sassafras (97)	Red oak (84)
5	Black cherry (27)	Yellow-poplar (75)	Sourwood (49)

On all study areas, we found a large number of species in this stem-size class. The three compartments on the excellent site had 10, 12, and 12 different commercial species. For the good site, the numbers were 14, 17, and 17; and for the fair site they were 13, 13, and 16. As occurred with the small stems, the good site exhibited the greatest diversity of species.

Several factors have a pronounced influence on the species composition of the large reproduction at 7 years. One is site quality, the effect of which was discussed in the previous section dealing with "small stems". Shade tolerance, too, has an effect, in that the species that were abundant as advance reproduction under the old canopies, such as sugar maple, got a jump on the others. Sprouting vigor, as exemplified by red maple and basswood, put these species in the forefront. Another species-related characteristic that favors

early fast growth is the propensity to root suckering, as exhibited by black locust and sassafras.

We compared species composition of new reproduction to the species composition of the old stand and the seed trees. With some exceptions, the predominant reproduction in the new stand was correlated in general to the most numerous species in the old stand, although the numerical order was somewhat different. An outstanding exception concerns red oak on excellent sites. Red oak was one of the most numerous sawtimber-size trees in the old stand, but constituted only a very small proportion of the reproduction. Several species, because of their prolific seeding characteristics, light seed, or heavy reproduction by root suckers, were more prominent in the new stand than in the old. These were sweet birch, sassafras, hornbeam, black locust, and yellow-poplar. With the exception of yellow-poplar, these species are short-lived, and most of them can be expected to drop out before rotation age.

Although we have no measurement of this, we feel that the seed trees did not have an appreciable effect on either the species composition or the abundance of stems in the new stand. Many of the stems present in the new stand came from small stems that existed at the time the old stand was cut. No doubt many of the new stems came from dormant seed in the duff, and many of them resulted from the current year's seed crop at the time the stands were harvested. The concensus of silviculturists is that seed trees are not needed to reproduce new hardwood stands.

REPRODUCTION QUALITY

No observations were made on the stem quality of *small reproduction* other than to tally it by seedlings (including sprouts from stumps less than 2 inches in diameter and root suckers) and stump sprouts (from stumps 2 inches in diameter and larger). At 7 years, percentages of sprouts were: excellent sites—11; good sites—23; and fair sites—22 (table 2).

Large reproduction was tallied as: (1) seedlings or sprouts, and (2) good or poor stems (table 3, and figs. 3 and 4). Good stems were straight and free from rot and mechanical injury; the others were classified as poor.

The percentage of total large stems that were sprouts went up as site quality decreased. On the excellent sites, sprouts averaged 56 percent of total stems; on the good sites, 61 percent; and on the fair sites, 71 percent (table 2). The higher sprouting incidence on the lower sites could have occurred because the previous stands there were younger when cut, and because they contained many more red maples, a vigorously-sprouting species.

For each site-quality class, seedlings averaged better quality than sprouts (table 3). For all areas on all sites, using

Table 3.—Stem quality of large reproduction

Compartment number	Percent of total stems that were sprouts	Percent of stems that were classified as good quality	
		Seedlings	Sprouts
	EXCELLENT SITE		
32	59	77	53
33	55	61	59
43	52	66	43
Average	56	68	52
	GOOD SITE		
36	68	56	43
37	57	53	51
39	58	63	40
Average	61	57	45
	FAIR SITE		
34	77	39	43
35	58	53	53
38	80	63	40
Average	71	52	45

Figure 3.—Well-formed stems of large reproduction.

the t-test for paired data, the difference was significant at the 5-percent level. Observations lead us to believe, however, that if we had used in the comparison only the best quality stems of each sprout clump, the differences between the two groups would have been much less pronounced or might not even have existed.

Figure 4.—A poorly-formed stem of large reproduction.

NONCOMMERCIAL SPECIES VALUABLE TO WILDLIFE

We tallied three noncommercial species that are important suppliers of wildlife food: pin cherry, flowering dogwood, and downy serviceberry. Strictly speaking, these species are not always noncommercial in all locations. When they grow large enough, they are included with pulpwood in this area.

At 7 years, and including both large and small stems (most stems were small), the average numbers per acre by site classes were:

Excellent sites: Pin cherry—59, dogwood—44, and serviceberry—7.

Good sites: Pin cherry—17, dogwood—452, and serviceberry—103.

Fair sites: Pin cherry—148, dogwood—208, and serviceberry—260.

The data seem to indicate that these species are more likely to form an appreciable component of new even-aged stands on sites below average quality. Serviceberry, in particular, appears to compete better in stands on lower-quality sites.

INDICATED POTENTIAL EFFECT OF EARLY CULTURAL TREATMENTS

On the Threat to the New Stand Posed by Large Advance Reproduction

Two kinds of observations gave us a measure of the potential threat to the development of the new stand posed by the 1- to 5-inch stems that remained after the seed trees were harvested. Most of these residual stems were too poorly formed or —after 7 years of growing in the open—too badly feathered out to make good crop trees themselves. The observations made were: (1) the number of these residuals, and (2) an estimate of the percentage of the total area dominated by their crowns (based on the percentage of milacres

receiving what we judged to be shade sufficiently dense to retard the growth of intolerant species).

Although they have had little apparent effect as yet on the number and development of the new stems, many of them will continue to grow, expanding their crowns and eventually becoming wolf trees. Because these stems were treated differently on different compartments, we also have a measure of the effect of treatment in reducing the threat they pose.

First, look at the number of 1- to 5-inch residuals on the four compartments on which they were tallied—32, 39, 36, and 43 (unfortunately they were not tallied on all compartments).

On compartments 32 and 39, where no treatments were made until the crop-tree release, the tallies showed 53 and 129 advance reproduction stems per acre present before crop-tree release and 33 and 62 left after crop-tree release (table

Table 4.—Advance reproduction stems (1- to 5-inch residuals) and the effects of treatment

Comp. No.	Residual stems per acre		Area dominated by residual stems	
	Before crop-tree release	After crop-tree release	Before crop-tree release	After crop-tree release
	No.	*No.*	*Pct.*	*Pct.*
	EXCELLENT SITE			
32	53	33	18	11
33	([1])	([1])	13	[2]13
43	0	0	0	0
	GOOD SITE			
36	([1])	22	29	13
37	([1])	([1])	58	[2]58
39	129	62	47	18
	FAIR SITE			
34	([1])	([1])	49	38
35	([1])	([1])	53	[2]53
38	([1])	([1])	22	2

[1] Tallies not made.

[2] Same as before release because no crop-tree release was made.

4). On compartment 36, where they were basal-sprayed at 3 years, we did not count them before crop-tree release, but after crop-tree release we found 22 per acre. These had been reduced from an unknown number by a combination of early basal spraying and a later crop-tree release. On compartment 43, these stems were cut at 3 years when seed trees were removed, and all of them were eliminated (fig. 5). Obviously cutting the stems was more effective than basal spraying.

Partly because data were taken on all nine compartments, the percentage of area dominated by residuals (based on the percentage of milacres receiving what we judged to be shade sufficiently dense to retard the growth of intolerant species) may be the better measure of the influenc of residuals (fig. 6). It may also be a better indicator of the improvement brought about by the elimination of 1- to 5-inch residual stems.

On the total of 6 compartments where no stem treatments were made before crop-tree release, shading at 7 years and before release affected an average of 40 percent of the area. This is a good indication of the shading effect we might

Figure 5.—All large residual advance reproduction stems were cut on this area.

Figure 6.—Residual large advance - reproduction stem casting shade on new stand.

expect if no precommercial cultural work is carried out in young stands.

On the three areas where the first treatment was a crop-tree release (32, 39, 34), the percent of areas shaded was 18, 47, and 49 percent before the release and 11, 18, and 38 percent after it. The crop-tree release brought about an average reduction in shading of 40 percent.

On compartment 43, where all the residual stems were cut at 3 years, none of the area was shaded at 7 years, either before or after crop-tree release. On compartments 36 and 38, where the residuals were basal-sprayed at 3 years, the percent of area shaded before crop-tree release was 29 and 22. The shading was reduced by crop-tree release to 13 and 2 percent.

On Future Species Composition of Stands

As a measure of the effect of early cultural work on species composition, we compared the composition of the stand of large reproduction before crop-tree release to the composition of the stand of released crop trees. The rationale for

using this comparison was an assumption that the unreleased stand would provide a species mix in the final crop proportional to what it was at 7 years, and that the released tree stand would do the same.

The yardstick used in this comparison was the proportion of favored species, which were: for the excellent and good sites —yellow-poplar, black cherry, white ash, basswood, red oak, and cucumbertree; for the fair site—the same species (most of them except red oak occur frequently on the fair sites) plus black, white, and chestnut oaks, and red maple.

A comparison of the proportion of stems of favored species shows clearly that crop-tree release has, at least temporarily, improved the species composition prospects for the future stand (table 5). For the six compartments where crop trees were released, the percentages of crop trees falling in the favored species group were 61, 92, 98, 100, 100, and 100. At 7 years, before crop-tree release, these same compartments

Table 5.—Percentage occurrence of favored species among the five most numerous species

Compartment number	Large reproduction at 7 years before crop-tree release	Among released crop trees
	EXCELLENT SITE	
32	15	92
33	44	([1])
43	29	98
	GOOD SITE	
36	26	61
37	50	([1])
39	28	100
	FAIR SITE	
34	66(20)[2]	100(40)[2]
35	35(3)[2]	([1])
38	61(13)[2]	100(52)[2]

[1] No cultural work was done in these compartments.

[2] Percent of stems that are red oak, the most favored species on fair sites.

had the following percentages of large reproduction stems in favored tree species: 26, 15, 29, 28, 66, and 61.

For the fair site, a more precise way to evaluate the species upgrading effect of crop-tree release might be to look only at red oak, the most favored species. Red oak comprised 40 and 52 percent of the released crop trees, but only 20 and 13 percent of the unreleased large reproduction (table 5).

Until more time has passed, we cannot be sure that the crop-tree composition will be maintained to the end of the rotation, nor can we ignore the fact that the commercial thinnings that will be made later in the untreated compartments (33, 37, and 35) will, to some extent, upgrade the species composition of these stands. But it appears now that crop-tree release has improved the potential species composition of the final stand.

Conclusions

1. At 7 years, both small and large stems of commercial species were abundant and well-distributed.

2. Species composition of the small reproduction at 7 years differed little from what it was at 3 years. However, at 7 years this size class was no longer dominant reproduction.

3. Large reproduction was composed mostly of species that had at least one of the following characteristics: (1) great sprouting vigor (red maple and basswood); (2) shade tolerance, permitting a start under the old stand (sugar maple); (3) unusually fast early growth (black cherry); and a (4) tendency to root-sucker (black locust and sassafras).

4. Species composition was strongly influenced by site quality, but a wide variety of species was represented on all sites and all study areas.

5. Seedlings and seedlings sprouts had better stem form than sprouts. However, if we had used in the comparisons

only the best quality stems of each stump sprout clump, the difference between the two groups would have been much less pronounced or might not have existed at all.

6. Early indications are that residual stems (those that were 1- to 5-inches d.b.h. when the old stands were cut) have potential for adversely affecting the new stand through shading it. Cutting these stems was more effective in eliminating them than was basal spraying.

7. Comparing the percentages of favored species found in the unreleased large-stem population to the released crop-tree population showed that crop-tree release had potential to improve species composition on all sites.

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Appendix

COMMON AND SCIENTIFIC NAMES

Hickory (*Carya* sp.)
Sugar maple (*Acer saccharum* Marsh.)
Red oak (*Quercus rubra* L.)
White oak (*Q. alba* L.)
Black cherry (*Prunus serotina* Ehrh.)
Yellow-poplar (*Liriodendron tulipifera* L.)
Chestnut oak (*Q. prinus* L.)
Black gum (*Nyssa sylvatica* Marsh.)
Red maple (*Acer rubrum* L.)
Sweet birch (*Betula lenta* L.)
White ash (*Fraxinus americana* L.)
Sassafras (*Sassafras albidum* (Nutt.) Nees)
Black locust (*Robinia pseudoacacia* L.)
Basswood (*Tilia* sp.)
Eastern hophornbeam (*Ostrya virginiana* (Mill.) K. Koch)
Sourwood (*Oxydendrum arboreum* (L.) DC.
Pin cherry (*Prunus pensylvanica* L. f.)
Flowering dogwood (*Cornus florida* L.)
Downy serviceberry (*Amelanchier arborea* (Michx. f.) Fern.
Black oak (*Quercus velutina* Lam.)
Cucumbertree (*Magnolia acuminata* L.)

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Seedling Survival in Spruce-Fir After Mechanical Tree Harvesting in Strips

by Robert M. Frank
and Eugene L. Putnam

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 12 JUNE 1971

SMALL SEEDLINGS SURVIVE

MECHANICAL TREE HARVESTING is a fairly new venture in the northeastern spruce-fir forests. These machines, either track or wheel mounted, are capable of performing one or several processing functions with a minimum of help from men on the ground. The Beloit machine, used for this study, crawls into a stand, grasps a tree and quickly trims off the branches, clips off the top, shears it off at the base, and then lays the branchless and topless tree in a pile for rubber-tired skidders to haul away.

Use of these machines has prompted several questions about the natural ability of the cleared strips to produce a new crop of trees of the desired species. It is known that reproduction is usually present in spruce-fir stands. The specific questions are: How much damage is done to the stocking of seedlings in the understory during the harvesting operation? And what happens to the surviving seedlings in their drastically changed environment?

Some answers to these questions were obtained in a recent study in Maine. We concluded that, after winter logging with a mechanical harvester, the stocking of surviving seedlings in most of the logged areas remains adequate for at least 2 years after logging.

THE STUDY

The study was begun in 1966 in a spruce-fir forest 35 miles west of Caribou, Maine (46° 50″ N. latitude, 68° 42″ W. longitude), at an elevation of approximately 700 feet. The topography is mostly flat to gently sloping, with maximum grades of about 20 percent. The study was restricted to stands containing at least 50 percent spruce and fir by volume.

This was a cooperative study, done on land owned in common, undivided, and managed by the following: Pingree, Wheatland, and Phillips Interests, managed by Seven Islands Land Co.; Great Northern Paper Co.; Griswold Heirs, managed by Prentiss and Carlisle Co., Inc.; and J. M. Huber Corp.

Here in northern Maine, winter is long, and snow is likely to form a cover from November through April. The frost-free season is approximately 100 days. The mean annual temperature is 40° F., and the average annual precipitation is 40 inches.

Stand composition and structure before harvesting were largely the result of two major occurrences during the early part of this century—a commercial harvest around 1900 and spruce budworm mortality and salvage operations in the early 1920's. Dominant and codominant trees averaged 50 to 65 feet tall. The stand contained about 310 trees per acre, totaling 1,855 cubic feet of gross volume in trees 5.0 inches d.b.h. and larger. About 75 percent of the volume was red spruce (*Picea rubens* Sarg.), white spruce (*P. glauca* (Moench) Voss), and balsam fir (*Abies balsamea* (L.) Mill.). Associated softwoods and hardwoods accounted for the remaining 25 percent.

In the winter of 1965 to 66, parts of the stand and the lower portions of adjacent hardwood slopes were logged experimentally. A Beloit Tree-Harvester (fig.1) was used in the logging, and Beloit grapple skidders (fig. 2) were used

Figure 1.—The mechanical tree harvester in operation.

Figure 2.—A four-wheel rubber-tired skidder hauls a load of stems to a landing.

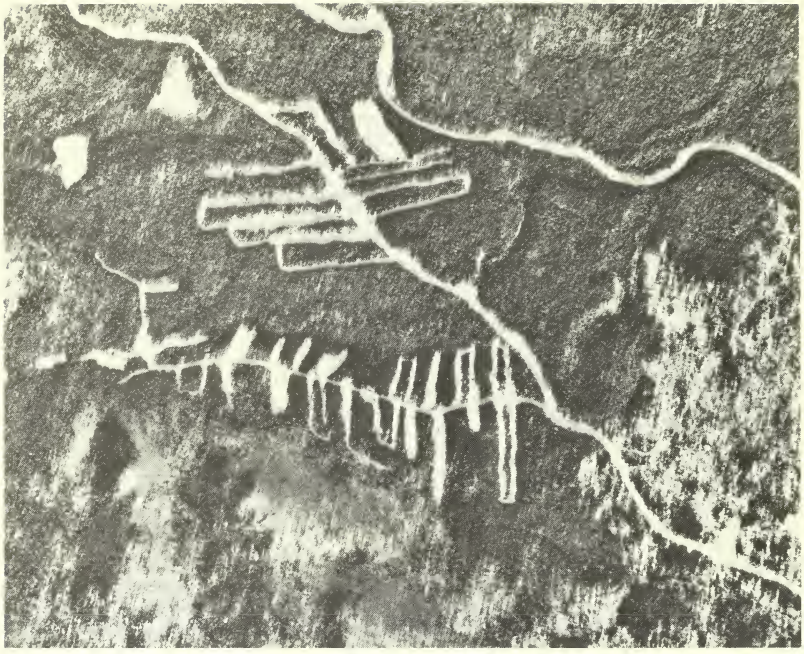

Figure 3.—An aerial view, showing the pattern of cleared strips.

to haul out the stems. (Mention of these products is for information only, and is not intended as an endorsement by the Forest Service or the U. S. Department of Agriculture.)

The timber was harvested in cleared strips (fig. 3).

PROCEDURES

To determine whether or not an adequate distribution of seedlings was present both before harvest and 1 and 2 years after harvest, rectangular ¼-milacre sample plots were installed in seven randomly selected cleared strips.

The plots were systematically distributed in portions of the seven strips, which varied in length from 300 to 1,300 feet. Strip widths were approximately 50, 100, and 200 feet. The strips were oriented in five directions, ranging from east-west to north-south.

There were 667 sample plots, each measuring 2.5 feet by 4.36 feet. Ninety of these were established 30 feet into the residual stand, adjacent to the cleared strips, for estimating the pre-harvest stocking. Locations of the 90 plots and the remaining 577 plots within the cleared strips were on transects evenly spaced along the portions of strips to be sampled. The number of transects per strip varied from 13 to 20, depending primarily on total length of the strip. All transects were more than 60 feet from a road, landing, or other clearing.

For strips 50 feet wide, each transect contained three plots —one at the center and one 10 feet from each edge. For strips wider than 50 feet, additional plots were installed 20 feet from each edge. Where necessary, plot locations were adjusted to have each plot represent only one combination of site conditions.

Site conditions at plot locations were recorded by (a) direct sunlight exposure class, (b) slash density class, and (c) logging area class.

Exposure classes were derived from the results of a study that illustrated the pattern of sunlight and shade in small forest clearings (*15*). Shade was defined as the open shade cast by trees along the borders of small clearings. Three exposure classes were used:

Minimum exposure— 0 to 20 percent of full sunlight.
Medium exposure —21 to 50 percent of full sunlight.
Maximum exposure—51 to 100 percent of full sunlight.

The measure of slash density was subjective. Three classes were recognized. Density was determined by the percentage of the plot surface visible from a point directly overhead. Density classes were:

Light slash—51 to 100 perecent of plot surface visible.
Moderate slash—26 to 50 percent of plot surface visible.
Heavy slash—0 to 25 percent of plot surface visible.

The differences in ground conditions caused by the passage of machines can influence seedling survival. Accordingly, two logging area classes were used:

On skid roads—plots located in areas in cleared strips displaying evidence of repeated machine passage.
Off skid roads—all other plots.

OBSERVATIONS

Plot establishment and initial observations were made during the fall of 1966, one growing season after logging. The second and final observations were made during the fall of 1967. Evidence has been reported elsewhere that 2 years is ample time in which to observe initial seedling survival after logging (*8*). Mortality is greatest during this period, and the rapid invasion of shrubs and other growth usually has not resulted in severe competition.

Observations on plots were limited to the presence or absence of seedlings of three species groups—spruce and fir, hardwoods, and all species combined. Size and vigor of the plant were not limiting criteria. The problem of defining an established or advance seedling remains elusive because even low-vigor seedlings on seemingly hostile sites do survive and develop into thrifty trees (*14*). For this study, a seedling was recorded if it was living and if it originated within the plot.

ANALYSIS

Plot means were based on the percent stocking of surviving seedlings observed on all plots (table 1). Also, partial data were analyzed to answer two questions. QUESTION 1: What is the lowest expected percent stocking 1 and 2 years after logging? A t-test for 5 percent probability was used to calculate half-confidence intervals for seedlings subjected to maximum exposure and to the various slash densities (table 2). QUESTION 2: Is there significant difference in mean percent stocking between skidroad and nonskidroad areas? Data were analyzed by analysis of variance.

Table 1.—Distribution of seedlings by species groups, exposure class, and slash density class, 1 and 2 years after harvest

Exposure class	Species group	Years since harvest	Slash density class			Mean percent stocking
			Heavy	Medium	Light	
		Years	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Minimum	Spruce and fir	1	50	60	86	69
		2	44	55	86	66
	Hardwoods	1	56	95	97	86
		2	31	80	93	74
	All species	1	62	100	100	91
		2	56	90	97	85
Moderate	Spruce and fir	1	51	83	78	75
		2	37	73	70	65
	Hardwoods	1	51	80	85	80
		2	31	81	77	70
	All species	1	65	98	92	89
		2	51	97	85	82
Maximum	Spruce and fir	1	60	85	82	76
		2	54	69	78	69
	Hardwoods	1	67	93	89	84
		2	44	73	77	67
	All species	1	79	95	97	96
		2	68	86	93	85
Mean percent stocking	Spruce and fir	1	55	80	80	74
		2	46	69	74	67
	Hardwoods	1	59	92	87	82
		2	38	78	78	69
	All species	1	72	97	94	90
		2	60	91	89	83

Table 2.—The percent stocking of surviving seedlings exposed to maximum direct sunlight, by species group slash density class, and years since harvest

Characteristics of sample populations					Lowest 10-percentile in which the true mean may be located[1]						
Species group	Slash density class	Years since harvest	Sample mean	Lower confidence limit	90	80	70	60	50	40	30
		Number	*Percent*	*Percent*							
All species	Light	1	98.2	92.2	*	—	—	—	—	—	—
		2	94.5	86.7	—	*	—	—	—	—	—
	Medium	1	96.9	85.5	—	*	—	—	—	—	—
		2	88.7	69.8	—	—	—	*	—	—	—
	Heavy	1	79.9	76.8	—	—	*	—	—	—	—
		2	67.6	58.7	—	—	—	—	*	—	—
Hardwoods	Light	1	93.9	86.8	—	*	—	—	—	—	—
		2	78.9	77.6	—	—	*	—	—	—	—
	Medium	1	94.3	86.2	—	*	—	—	—	—	—
		2	71.7	67.4	—	—	—	*	—	—	—
	Heavy	1	68.8	67.9	—	—	—	*	—	—	—
		2	48.8	48.0	—	—	—	—	—	*	—
Spruce and fir	Light	1	82.9	78.4	—	—	*	—	—	—	—
		2	79.1	72.6	—	—	*	—	—	—	—
	Medium	1	87.1	63.8	—	—	—	*	—	—	—
		2	68.4	45.7	—	—	—	—	—	*	—
	Heavy	1	58.2	44.2	—	—	—	—	—	*	—
		2	50.9	35.3	—	—	—	—	—	—	*

[1] Based on a probability of 0.95

RESULTS AND DISCUSSION

Seedling Characteristics Before Harvest

Observations made after logging in the adjacent undisturbed stand indicated that mean percent stocking was adequate in the cleared strips before logging. Seedling distribution was:

Species	*Stocking percent*
Spruce and fir	99
Hardwood	91
All species	100

Average height of the tallest spruce and balsam fir seedlings was estimated to be about 6 inches. The hardwoods included red maple (*Acer rubrum* L.), sugar maple (*A. saccharum* Marsh.), and yellow birch (*Betula alleghaniensis* Britton). The tallest hardwood seedlings were about 9 inches. An associated conifer, northern white-cedar (*Thuja occidentalis* L.) averaged less than 6 inches in height.

Most seedlings present at the time of harvest were less than 1 foot tall, and it is these smaller seedlings that are least susceptible to logging damage (*11, 19*). Many seedlings were afforded some protection by the snow cover, which exceeded 1 foot in depth (*12, 20*). Had the average seedling height been greater or the amount of snow less, the cover of snow might not have been protective at all. And the stocking figures after harvest might not have been so high.

Seedling Survival After Harvest

The tree-harvester created little discernible disturbance to the forest floor. As the machine moved from tree to tree, it "floated" on slash previously deposited. But compaction of slash did occur. Tree-length skidding with rubber-tired skidders created skidroads and even caused some windrowing of slash along these roads. Some disturbance to the forest floor—but very little soil disturbance—resulted from

Figure 4.—Compaction of slash in this cleared strip is still evident 1 year after harvesting.

skidder passage. These conditions remained visible after snow melt (fig. 4). This observation is similar to results reported for both summer and winter operations in spruce-fir forest types and for other kinds of logging systems (*2, 3, 9, 11, 19*).

Initial survival as expressed by percent stocking was good both 1 and 2 years after harvest (table 1). Overall losses during the first year, including an indeterminate amount of logging damage, resulted in a 10-percent reduction in mean stocking—from 100 percent to 90 percent. Losses during the second year amounted to a reduction of an additional 7 percent, to 83 percent stocking.

Spruce and fir losses exceeded hardwood losses, but only slightly. Mean percent stocking dropped from 99 percent before harvest to 74 percent and to 67 percent 1 and 2 years after harvest respectively. Comparable figures for hardwoods were 82 percent and 69 percent from a mean percent stocking of 91 percent before harvest. Thus the reductions in

stocking at the end of 2 growing seasons were about one-third in spruce and fir and about one-quarter in hardwoods.

It is apparent that meaningful differences in survival were caused by variations in slash density. Specifically, it was the heavy accumlations of slash that caused maximum seedling mortality. Death was probably hastened by dense slash piles because they physically crushed seedlings and inhibited the penetration of both moisture and light to the seedbeds beneath (*1, 5, 10, 13, 16, 18, 21*).

Apparently precipitation was adequate and well distributed during both growing seasons. The near-normal amounts of moisture possibly prevented mortality among seedlings located within areas of maximum exposure. Adequate soil moisture conditions throughout the growing season can prevent critical moisture stresses within plant tissues (*7*). And with necessary rainfall, lethal air or surface soil temperatures are not likely to be reached even on seedbeds exposed to direct sunlight for long periods of time.

Two years after harvest, the mean stocking of spruce and fir under heavy slash accumulations and all exposure classes combined was 46 percent, or about one-third less than the other density classes. Hardwood stocking under similar conditions was about one-half that found in the less dense slash classes. Stocking was only 38 percent. And the mean stocking of all species under heavy slash, at 60 percent, was two-thirds that found in the other classes.

Lowest Expected Percent Stocking

Stocking of surviving seedlings 1 and 2 years after harvest on the portions of sample strips receiving maximum direct sunlight exposure was lowest for spruce and fir seedlings under heavy slash. Low stocking levels also occurred both for spruce and fir under medium slash and for hardwoods under heavy slash. All other stocking levels were good or extremely good. This analysis was based on data obtained from the four sample strips containing the necessary number of plots sufficient for statistical investigation.

The lowest confidence limit was 35.3 percent stocking for spruce and fir under heavy slash—the only lower limit to be included within the 30th percentile (table 2). Spruce and fir stocking under medium slash and hardwood stocking under heavy slash were both within the 40th percentile, with lower confidence limits of 45.7 percent stocking and 48.0 percent stocking respectively. No other combination of species and slash densities resulted in stocking levels below the 50th percentile at the end of 2 years.

Stocking levels under light slash were all high. The lowest stocking under light slash, recorded for spruce and fir, was within the 70th percentile.

Effect of Skidroads on Survival

Mechanical damage caused only minor to moderate reductions in stocking on logged areas classified as skidroads. Damage was estimated by comparing mean percent stocking of plots on skidroads with those off skidroads (fig. 5).

At the end of two growing seasons, reductions in stocking under light slash, the predominant slash density found on the skidroads, and under all exposures combined were 20.1 percent in spruce and fir, 6.8 percent in hardwoods, and 8.2 percent for all species.

The differences, within a species group, on on-skidroad and off-skidroad stocking levels did not change appreciably in 2 years. This indicates that seedling survival was not seriously affected by the differences in micro-environment caused by skidroads.

Statistically there were some significant differences in survival due to logging. Survival of spruce and fir and survival of all species was significantly less on skidroads both years. Differences were not significant for hardwoods either year. However, since the lowest stocking mean reported was above 60 percent on skidroads and above 80 percent off skidroads, the statistical significance is not very meaningful. It does indicate that machine passage during winter conditions does

cause some mortality to the small seedlings present at time of harvest, but the amount is not critical.

RECOMMENDATIONS AND CONCLUSIONS

- The stocking of spruce and fir and hardwood seedlings under 1 foot in height was not seriously reduced by a wintertime Beloit Tree-Harvester operation in cleared strips. Surviving stocking is adequate for a period of at least 2 years after logging. These results were obtained in

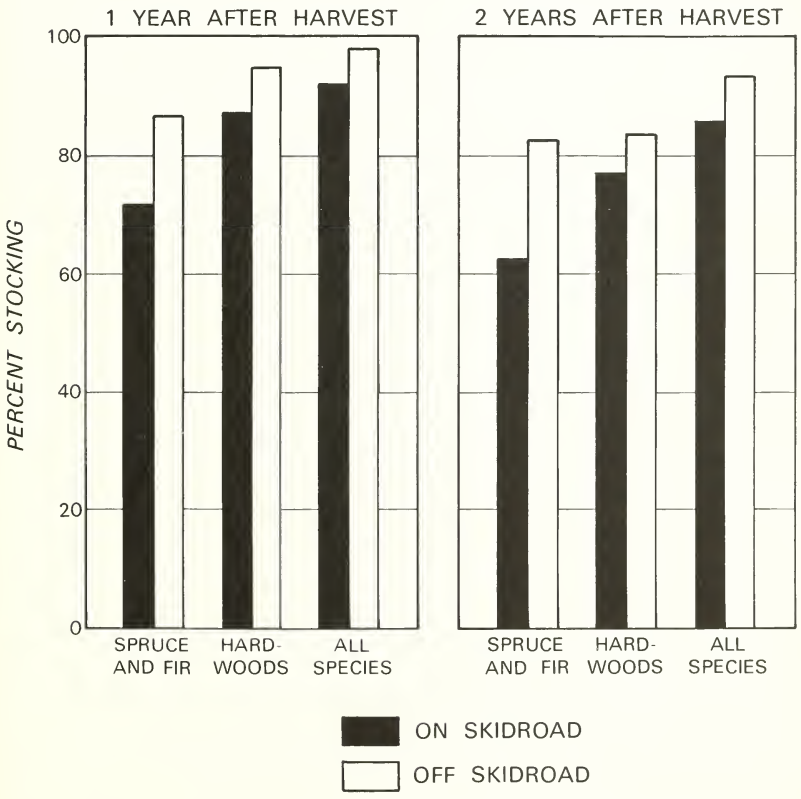

Figure 5.—The mean percent stocking of surviving seedlings 1 and 2 years after harvesting, under light slash and all exposures.

stands containing at least 50 percent spruce and fir by volume.

- Heavy slash accumulations create the least favorable site conditions for seedling survival. Until the benefits, if any, of dense piles of slash can be demonstrated, we recommend that heavy concentrations of slash be avoided.
- Since all the environmental factors that affect seedling survival in cleared strips were not measured in this study, we recommend that strip width not exceed 200 feet. Other workers suggest that narrow strips, preferably not exceeding one-half of stand height, be cleared if spruce and fir is to be favored over hardwoods.
- Length of strip probably will not be a factor in stocking of skidroads if total length does not exceed ¼ mile. Repeated machine passage over skidroads in longer strips could result in excessive seedling damage and mortality. We therefore recommend that a second skidroad be established if strip length is greater than ¼ mile. Not to be completely discounted are the potential beneficial aspects, as suggested by others, of skidroads receiving overuse on strips otherwise regenerating too densely.

The area in which this experiment was conducted was the location for the first trial of tree-length mechanical harvesting in the spruce-fir forests of the Northeast. Other equipment and other harvesting schemes have since been tested, and testing will no doubt continue until completely mechanical systems are developed. The cooperators strongly suggest that research monitor all aspects of machine operations as they relate to the natural as well as the artificial regenerative capacity of the spruce-fir forest. Left unanswered is the question of cultural treatments required within the cleared strips to hasten and ensure development of the desired new stand. Likewise, in either alternate or progressive strip operations, the timing of the harvest of an adjacent strip is also left unanswered.

The recommendations listed above are a beginning.

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Use of HARDWOOD DIMENSION STOCK by the Southern FURNITURE INDUSTRY

by R. Bruce Anderson
and Paul E. Sendak

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1972

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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DIMENSION STOCK—timber cut into specified thicknesses, widths, and lengths—is used widely in the furniture industry. This industry is the main market for the manufacturer of dimension stock.

To help the manufacturer of dimension stock supply this market effectively and profitably, we have made a study of the southern furniture industry. We concluded that the independent manufacturer of dimension stock may find it hard to increase his share of this market in the future, because most furniture plants are now making much of their own dimension stock.

THE STUDY

Furniture firms were studied in the 16 states comprising the three southern regions established by the United States Department of Commerce (fig. 1). All firms manufacturing some form of wooden furniture were included in the study. However, it is significant that firms manufacturing wood household furniture—not upholstered furniture—accounted for about 85 percent of the hardwood lumber and parts consumed by the United States furniture industry in 1960 (*2*).

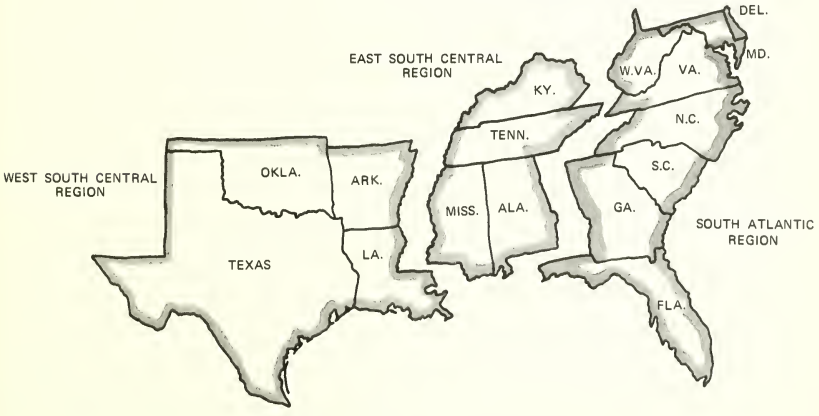


Figure 1.—The survey region.

A list of 2,175 furniture-manufacturing firms was compiled for the study area. The firms were classed by number of employees and by geographic location (appendix, table 1).

A questionnaire was mailed to each firm to determine the attitudes of the furniture manufacturers toward purchasing dimension stock. Information was obtained about the characteristics of each firm, including: employment; product diversification; lumber use; type, value, and frequency of dimension parts purchased; factors considered in purchasing; reasons for purchasing or not purchasing; and plans for future purchase of dimension stock. Information was also obtained about the dimension stock produced by the furniture manufacturers.

Three separate mailings were made over a 7-week period. A follow-up survey by telephone was made of a subsample of firms that did not respond, to determine if their opinions and attitudes differed in any way from those firms that did respond to the mailed questionnaire. The questions asked in the telephone survey were the same as those in the mailed questionnaire; although the survey was less comprehensive. No significant differences were found between those firms that did respond and those that did not.

CHARACTERISTICS OF RESPONDING FIRMS

Employment

The 635 firms who returned a usable questionnaire employed 94,673 full-time production workers in 1967. The average number of employees per firm was 149 (appendix, table 3). Over 58 percent of the responding firms were located in the South Atlantic Region; and their average number of employees was 157. Approximately 26 percent of the responding firms were located in the East South Central Region, and their average number of employees was 174. The remaining 16 percent of the responding firms were located

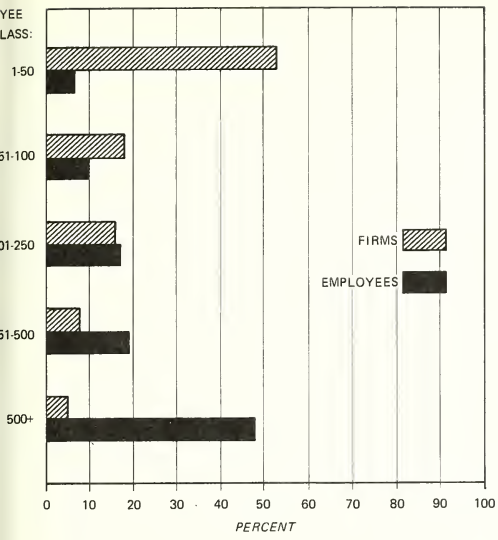


Figure 2.—Firm and employee distribution, by employee size classes.

in the West South Central Region, and they had an average of 103 employees.

Only 5 percent of the firms surveyed employed 500 or more production workers, while 53 percent of the firms employed fewer than 50 (fig. 2). However, the firms in the largest employee size class employed 48 percent of the total production workers, while the firms in the smallest employee size class employed only 7 percent.

Lumber Use

Almost 86 percent of the 635 firms used hardwood lumber or dimension stock in their plants (appendix, table 4). These 544 firms used 797 million board feet of hardwood lumber in 1967, for an average of 1.465 million board feet per firm. Sixty-nine percent of the firms used less than 1 million board feet of hardwood lumber (fig. 3). Those firms (6 percent of the total) with 500 or more employees used over 360 million board feet (45 percent of the total), an average of 10.64 million board feet of lumber per firm.

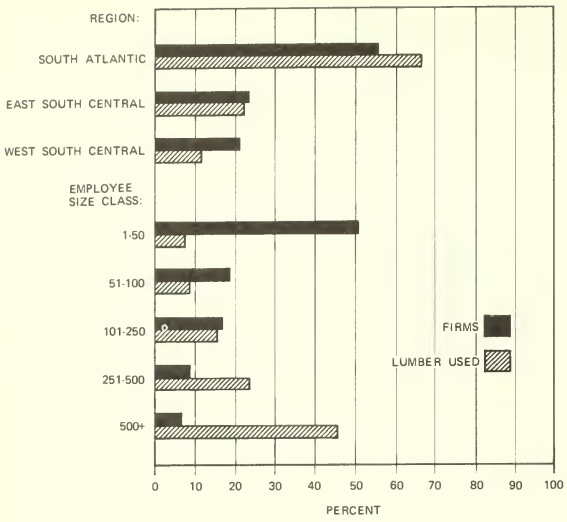


Figure 3.—Use of hardwood lumber by region and employee size class.

Dimension Purchased

Of the 544 firms that used hardwood lumber or dimension stock, 68 percent (372 firms) said that they purchase hardwood dimension. The types of dimensions stock most frequently purchased were:

Type of dimension	*Firms purchasing (No.)*
Turnings and carvings	173
Rough flat stock	142
Partially machined stock	116
Squares	107
Fully machined parts	78
Molding and trim	73

The 776 responses (appendix, table 5), from the 372 firms indicated that each firm purchases more than one type of dimension.

An analysis of the types of dimension stock purchased was made for furniture manufacturers who made only one type of furniture. Of the 544 firms that use hardwood lumber or dimension, 375 are single-product manufacturers. The close correspondence between the percent of single-product firms

that use the different types of dimension (appendix, table 6) and the percentages obtained from the 544 firm sample (appendix, table 5) justifies the conclusion that the analysis by type of furniture is representative of the total industry.

Turnings and carvings are used in 27 percent of the firms. Of the 12 types of furniture listed, the firms that produce upholstered and nonupholstered living room, dining room, radio and television cabinets, juvenile, and other furniture, purchase turnings and carvings more frequently than any other type of dimension.

Rough flat stock is used by 18 percent of the firms. It is purchased more often than other types of dimension by the firms producing kitchen cabinets, church—school—other public building furniture, and office furniture.

Partially machined stock is used by 15 percent of the firms. It is purchased more often than other types by firms producing outdoor and unpainted furniture.

Squares are used by 12 percent of the firms. They are purchased more often than other types of dimension by firms producing bedroom furniture.

Value of Purchased Parts

The total value of hardwood parts purchased by the 544 firms in 1967 was $60,390,382 (appendix, table 7). The average expenditure per firm in 1967 for purchased dimension was $201,197.

When the value of purchased dimension is considered, a different order of importance is obtained for the types of dimension (fig. 4). In terms of dollars expended for parts, the most important types of dimension purchased were:

Type of dimension	*Expenditure*
Partially machined stock	$13,147,102
Rough flat stock	12,839,249
Fully machined parts	11,442,328
Turnings and carvings	8,584,204
Squares	6,379,926

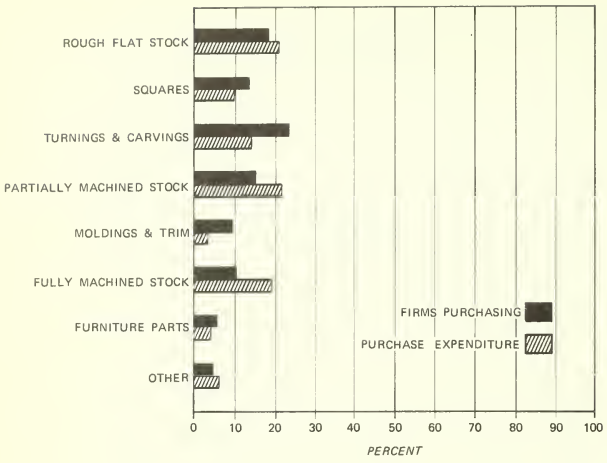


Figure 4.—Dimension part purchasing by furniture firms.

Firms in the South Atlantic Region accounted for over 50 percent of the total dollar value of hardwood dimension purchased.

North Carolina, Arkansas, and Mississippi, ranked in that order, had the largest dollar volume of hardwood dimension stock purchases and also had the largest dollar volume of hardwood dimension sales in 1967 (appendix, table 8). North Carolina had almost 25 percent of the total purchases and sales within the survey area, while the South Atlantic Region had 50.4 percent of the total purchases and 45.7 percent of the total sales. The purchases and sales for the three states listed above comprised over 55 percent of the total purchases and total sales (fig. 5).

Product Diversification

375 firms, or about 59 percent of the 635 respondents, indicated that they manufactured only one type of furniture (appendix, table 9). Generally, more of the smaller firms (those having fewer than 50 full-time production workers) produced a single type of furniture. In the sample of firms in the 1-50 employee size class, 60 percent produced a single type of furniture. In the 500-plus employee size class, 80

percent of the firms produced more than one type of furniture. The types of furniture produced by these single-product manufacturers, in order of importance, are:

Type of furniture	*Firms producing (No.)*
Upholstered living room	125
Kitchen cabinets	63
Miscellaneous furniture, not elsewhere classified (n.e.c.)	61
Church and institutional	34
Bedroom	29
Dining room	17
Nonupholstered living room	16

The producers of these types of furniture combined represent 92 percent of the single-product line manufacturers contacted in the survey.

The ranking above is true for the smaller firms; but 43 percent of the larger firms that produce single-product lines manufacture only radio and television cabinets.

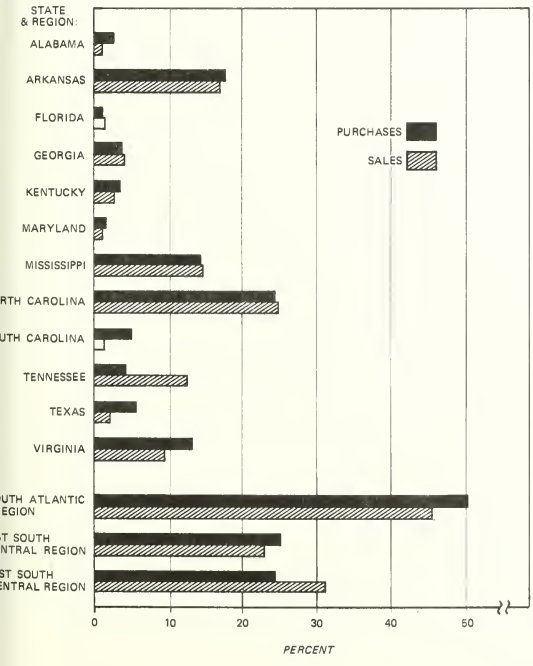


Figure 5.—Part purchases and sales, by state and region.

Ranking of firms by types of furniture produced differs when all firms in the survey area are considered (fig. 6). More than one type of furniture is produced by 260 of the 635 firms surveyed. Ranked by percent of firms that produce each type of furniture, the order of importance for each type is:

Type of furniture	*Firms producing (percent)*
Upholstered living room	19.0
Miscellaneous	13.0
Kitchen cabinets	12.5
Bedroom	11.5
Dining room	10.5
Church and institutional	10.0
Nonupholstered living room	8.0
Office	6.0
Radio and television cabinets	3.5
Outdoor and recreational	2.0
Juvenile	2.0
Mattress and bedspring frames	2.0
	100.0

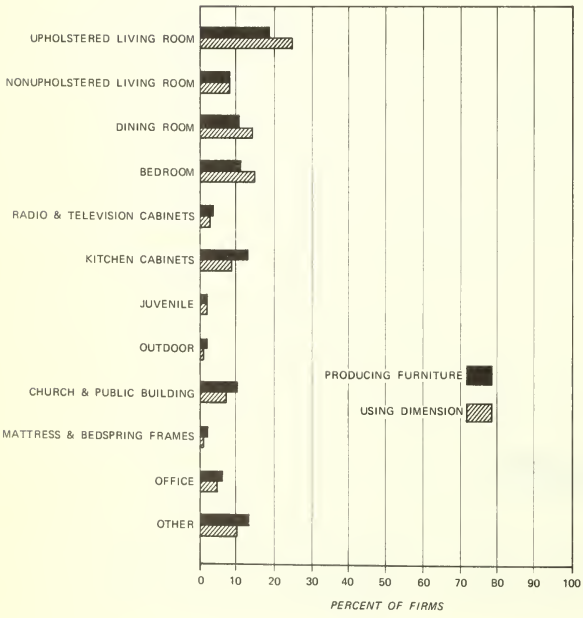


Figure 6.—Use of parts by furniture firms and by type of furniture produced.

Firms producing miscellaneous furniture (not elsewhere classified) ranked second in number and represented 13 percent of the 635 firms surveyed. Of the 635 firms, 526 indicated that they use hardwood dimension for a specific type of furniture (appendix, table 12). Ten percent of these firms produce miscellaneous furniture. A listing of the miscellaneous furniture products revealed three additional furniture industries that were not detailed on the survey questionnaire. Wood partitions, shelving, lockers, and office and store fixtures industry (SIC Code 2541) accounted for 59 percent of the products of firms producing miscellaneous furniture. The furniture and fixtures industry (not elsewhere classified; SIC Code 2599) accounted for 36 percent of the firms. Finally, the household furniture industry (not elsewhere classified; SIC Code 2519) made up the remaining 5 percent of the firms.

Within-Plant Manufacture

Most of the furniture firms produce in their own plants at least a majority of the hardwood parts they use. Only 33 percent of the respondents indicated that they did not manufacture any of the hardwood dimension they used. But 25 percent of the respondents indicated that all of the dimension parts they used were manufactured in their own plants. And 51 percent of the respondents manufactured over half of the hardwood dimension parts they used.

The proportion of hardwood dimension produced by furniture manufacturers should increase slightly after 1967. Almost 43 percent of the firms indicated that they planned to increase the proportion of hardwood dimension manufactured in their own plants (appendix, table 10). About 47 percent indicated that the proportion of within-plant production would stabilize; while 10 percent stated that the proportion would decrease.

Future Purchase of Dimension

The furniture manufacturers who indicated that they did not purchase dimension stock in 1967 were questioned about plans to purchase dimension in the future. Of the 256 firms, 63 percent planned not to purchase dimension within the next 3 years; 31 percent indicated that they did not have definite plans either way; and 6 percent indicated that they have definite plans for purchasing dimension in the next 3 years (appendix, table 11).

Of the 256 firms that were not purchasing hardwood parts, 65 percent do purchase hardwood lumber while the remaining 35 percent purchase neither lumber nor dimension.

Frequency of Use of Dimension

Furniture manufacturers were questioned to determine how many firms purchased dimension parts for the manufacture of the 12 types of furniture. The 372 firms that used dimension supplied 526 responses (appendix, table 12). The percent of firms purchasing dimension parts for each type furniture was:

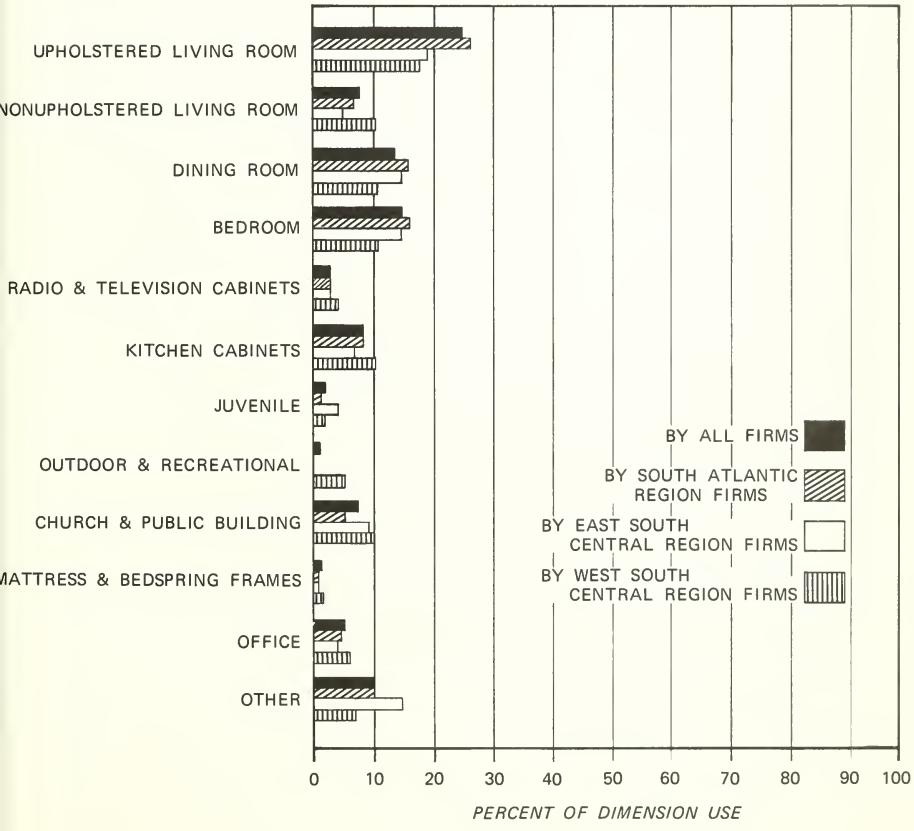
Type of furniture	*Purchased dimension (percent)*
Upholstered living room	25.0
Bedroom	15.0
Dining room	14.0
Miscellaneous	10.0
Kitchen cabinets	8.5
Nonupholstered living room	8.0
Church and institutional	7.5
Office	5.0
Radio and television cabinets	3.0
Juvenile	2.0
Outdoor and recreational	1.0
Mattress and bedspring frames	1.0
	100.0

The category of "other" furniture showed 55 firms (10 percent of the total) using purchased dimension. This category includes 32 firms (59 percent) producing partitions,

shelving and store fixtures; 20 firms (36 percent) producing furniture and fixtures, n.e.c.; and 3 firms (5 percent) producing household furniture, n.e.c.

The relative proportions of firms, purchasing dimension for manufacture of the different types of furniture, were essentially the same for all three regions (fig. 7). For example, the percent of firms purchasing dimension for the manufacture of upholstered living room furniture was: 26.5 percent of the firms in the South Atlantic Region; 24 percent of the firms in the East South Central Region; and 23 percent in the West South Central Region.

Figure 7.—Percent distribution of firms using purchased dimension, by type of furniture produced and by region.



Reasons for Purchase

The 372 furniture manufacturers who purchased hardwood dimension in 1967 were asked to rank their reasons for purchasing dimension. Ninety percent of the firms responded to the question. However, most firms ranked only those reasons that were pertinent to their operations (table 13).

Three methods were used for evaluating the importance of each reason for purchasing dimension. By considering only the number of firms that ranked each reason, an order of importance was obtained (column 9, table 13). By considering the number of firms that did not rank the question as the lowest order of ranking, and incorporating these as responses in the calculation of a rank value, the identical ordering was obtained (column 10, table 13).

In the third method we applied a factor to the rank values of the answers for the total number of firms (332). This method provided the same ranking as the other two methods except that reason No. 7 (other reasons) was ranked third instead of sixth (column 11, table 13). The reasons for purchasing were, in rank:

Rank	*Reason for Purchasing*
1	Furniture production capacity increased with little additional capital investment.
2	Premanufactured hardwood parts can be purchased for less cost than we can produce them for.
3	Allows better control of production costs.
4	Less space is needed for materials inventory.
5	Manufacturing waste is reduced.
6	Other reasons.
7	Lumber transportation costs are reduced.

Factors Considered in Purchasing

The factors considered most important when purchasing hardwood dimension were ranked by the 332 firms (table 14). Most firms ranked only those factors that were pertinent to their operations. The three methods for evaluating the importance of reasons for purchasing dimension were also used to evaluate the factors considered in purchasing. Analysis of the data resulted in the following ranking:

Rank	*Factors*
1	Price
2	On-time delivery
3	Species
4	Supplier's reputation
5	Machining tolerances
6	Lead time required
7	Moisture content
8	Grade specifications
9	Allowable amount of defective parts
10	Other

Reasons for Not Purchasing

The 256 firms who indicated that they did not purchase any hardwood parts in 1967 were asked to rank a series of choices indicating their reasons for not purchasing the parts. Eleven reasons were listed on the questionnaire. Ranking of these reasons is presented below:

Firms ranked (No.)	*Rank*	*Reason*
105	1	Manufacture own parts for less cost.
97	2	Have own production facilities and want to use them fully.
54	3	Quantities for furniture produced are too small to use purchased parts efficiently.
34	4	Manufacture some (or all) of listed hardwood parts for sales to others.
26	5	Listed parts are not used in our products.
9	6	Other.
12	7	Desired part sizes are not available.
9	8	Have not been solicited by dimension producers.
8	9	Hardwood parts of desired species not available.
7	10	Have been unable to obtain reliable delivery.
8	11	Parts that meet specifications not available.

CONCLUSION

Although the total use of hardwood dimension stock is expected to increase in the future, the independent dimension manufacturer will find it difficult to increase his share of the market to any substantial degree. The primary reason for this static market will be the increasing within-plant production of hardwood dimension parts by the furniture manufacturers. Over half of the furniture manufacturers already produce over half of their dimension requirements now in their own plants; and the ratio of furniture manufacturers planning increased within-plant dimension production versus those planning decreased production is higher than 4 to 1.

The attitudes of the furniture manufacturers toward the purchase of dimension stock appear to be based primarily upon cost factors. The primary reasons given for *not* purchasing hardwood dimension were also based on cost factors. Though cost of purchased parts—compared with cost of dimension parts produced within the plant—appears to be the main factor considered, other factors also were important, including (1) on-time delivery as opposed to time required for in-plant manufacture; (2) species of hardwood parts required; and (3) reputation of the supplier of dimension parts.

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APPENDIX

Table 1.—Employee size classification of strata

[Stratification of population]

Stratum No.	Employee size class	No. employees
	SOUTH ATLANTIC REGION	
1	1	1-50
2	2	51-100
3	3	101-250
4	4	251-500
5	5	500+
	EAST SOUTH CENTRAL REGION	
6	1	1-50
7	2	51-100
8	3	101-250
9	4	251-500
10	5	500+
	WEST SOUTH CENTRAL REGION	
11	1	1-50
12	2	51-100
13	3	101-250
14	4	251-500
15	5	500+

Table 2.—Response to mailed questionnaires

Item	Questionnaires	Percent of total mailed
	No.	*Pct.*
Total mailed	2,175	—
Total not returned	894	41.1
Total returned	1,281	58.9
Out-of-business	171	7.9
Unknown address	129	5.9
No wood used	221	10.2
Partially completed	81	3.7
Usable returns	679	31.2

Table 3.—Employment size

Stratum	Number of firms	Number employed	Mean employment
1	187	3,569	19
2	60	4,588	77
3	61	10,252	109
4	24	8,748	365
5	21	28,253	1,346
6	66	1,211	19
7	30	2,334	78
8	24	3,900	163
9	16	6,273	393
10	7	11,187	1,599
11	86	1,392	16
12	23	1,845	81
13	15	2,334	156
14	9	3,144	350
15	6	5,643	941
R1	353	55,410	157
R2	143	24,905	174
R3	139	14,358	103
EMP1	339	6,172	18
EMP2	113	8,767	77
EMP3	100	16,486	165
EMP4	49	18,165	370
EMP5	34	45,083	1,325
All strata	635	94,673	149

Table 4.—Use of hardwood lumber or parts

Employee size class	Number of firms that—				Lumber used	
	Use		Don't use		Volume	Average
	No.	*Pct.*	*No.*	*Pct.*	*Mbf.*	*Mbf.*
1	274	80.8	65	19.2	57,151	208.5
2	99	87.6	14	12.4	66,011	666.7
3	90	90.0	10	10.0	125,802	1,397.8
4	47	95.9	2	4.1	185,949	3,956.3
5	34	100.0	0	0.0	361,911	10,644.4
Regions						
1	304	86.1	49	13.9	527,115	1,733.9
2	126	88.1	17	11.9	178,666	1,417.9
3	114	82.0	25	18.0	91,043	798.6
Stratum						
1	152	81.3	35	18.7	34,291	225.6
2	51	85.0	9	15.0	25,725	504.4
3	57	93.4	4	6.6	83,089	1,457.7
4	23	95.8	1	4.2	100,177	4,355.5
5	21	100.0	0	0.0	283,833	13,515.9
6	54	81.8	12	18.2	12,776	236.6
7	28	93.3	2	6.7	25,452	909.0
8	22	91.7	2	8.3	26,063	1,184.7
9	15	93.7	1	6.3	65,843	4,389.5
10	7	100.0	0	0.0	48,532	6,933.2
11	68	79.1	18	20.9	10,084	148.3
12	20	86.9	3	13.1	14,834	741.7
13	11	73.3	4	26.7	16,650	1,513.6
14	9	100.0	0	0.0	19,929	2,214.3
15	6	100.0	0	0.0	29,546	4,924.3
All firms	544	85.7	91	14.3	796,824	1,464.7

Table 5.—Types of hardwood dimension stock purchased, by frequency of purchase

Stratum	Rough flat stock	Squares	Turnings and carvings	Partially machined	Mold and trim	Fully machined	Furniture parts	Other	Total response
1	42	11	49	22	24	15	14	13	190
2	15	6	24	9	2	7	4	2	60
3	17	23	24	17	6	11	2	4	104
4	3	11	7	4	2	2	1	0	30
5	4	10	9	6	4	5	1	3	42
6	12	3	4	3	4	3	1	3	33
7	4	5	14	5	4	3	2	1	38
8	6	8	11	11	4	7	4	0	51
9	4	5	4	4	2	1	0	4	24
10	6	6	4	4	3	5	4	0	32
11	18	4	14	12	10	6	3	3	70
12	2	3	6	6	5	5	2	1	30
13	3	4	5	3	2	3	4	0	24
14	4	4	5	6	1	4	1	0	25
15	2	4	3	4	0	1	0	0	14
R1	81	61	113	58	38	40	22	22	435
R2	32	27	37	27	17	19	11	8	178
R3	29	19	33	31	18	19	10	4	163
EMP1	72	18	67	37	38	24	18	19	293
EMP2	21	14	44	20	11	15	8	4	137
EMP3	26	35	40	31	12	21	10	4	179
EMP4	11	20	16	14	5	7	2	4	79
EMP5	12	20	16	14	7	11	5	3	88
All strata	142	107	183	116	73	78	43	34	776

Table 6.—Frequency of purchased dimension stock use, by kind of furniture produced, in percent

Type of furniture	Rough flat stock	Squares	Turnings and carvings	Partially machined stock	Moldings and trim	Fully machined stock	Furniture parts	Other
Upholstered living room	17	7	33	10	11	9	7	6
Nonupholstered living room	9	5	40	18	9	5	5	9
Dining room	10	23	29	20	6	6	6	0
Bedroom	12	25	23	13	4	15	4	4
Radio-television cabinets	15	15	37	11	11	11	0	0
Kitchen cabinets	33	0	3	24	22	9	0	9
Juvenile	9	9	28	18	18	9	9	0
Outdoor and/or unpainted	0	25	25	50	0	0	0	0
Church, school, or other public building	40	15	5	20	0	10	5	5
Mattresses and bedsprings	0	0	0	0	0	0	0	0
Office	43	14	14	29	0	0	0	0
Other	18	20	23	15	5	11	3	5
	18	12	27	15	9	9	5	5

Table 7.—Amount spent on hardwood parts in 1967

Stratum	Rough flat stock	Squares	Turnings and carvings	Partially machined stock	Moldings and trim	Fully machined parts	Furniture parts	Other	Total
1	$ 575,275	$ 75,670	$ 328,184	$ 441,325	$ 84,276	$ 576,130	$ 319,064	$ 374,930	$ 2,774,854
2	578,400	80,550	249,761	814,990	39,240	451,100	319,262	49,750	2,583,053
3	2,638,048	805,284	1,425,499	3,192,995	573,249	2,731,400	251,400	141,168	11,759,043
4	1,838,000	1,080,052	677,992	1,461,756	162,000	56,500	82,500	000	5,358,800
5	1,671,300	1,412,540	963,156	799,500	38,131	828,108	000	2,632,698	8,345,433
6	160,360	23,850	23,600	71,000	240	790,850	700	000	1,070,600
7	265,800	22,300	536,100	874,700	197,300	27,300	23,700	70,000	2,017,200
8	968,250	282,410	660,360	490,160	54,760	578,410	385,500	000	3,419,850
9	629,288	714,000	87,231	219,088	39,500	150,000	000	000	1,839,107
10	1,507,280	234,100	2,156,500	414,000	476,120	1,127,800	40,300	000	5,956,100
11	172,448	51,050	174,872	194,766	62,329	643,980	29,095	38,675	1,367,215
12	67,800	114,320	139,449	139,622	56,531	186,750	601,655	44,000	1,350,127
13	292,500	580,000	139,500	143,500	13,500	620,000	141,000	210,000	2,140,000
14	721,500	383,000	870,000	3,447,500	180,000	2,410,000	60,000	205,000	8,277,000
15	753,000	520,800	152,000	442,200	000	264,000	000	000	2,132,000
R1	7,301,023	3,454,096	3,644,592	6,710,566	896,896	4,643,238	972,226	3,198,546	30,821,183
R2	3,530,978	1,276,660	3,463,791	2,068,948	767,920	2,674,360	450,200	70,000	14,302,857
R3	2,007,248	1,649,170	1,475,821	4,367,588	312,360	4,124,730	831,750	497,675	15,266,342
EMP1	908,083	150,570	526,656	707,091	146,845	2,010,960	348,859	413,605	5,581,549
EMP2	912,000	217,170	925,310	1,829,312	293,071	665,150	944,617	163,750	8,191,061
EMP3	3,898,798	1,667,694	2,225,359	3,826,655	641,509	3,929,810	777,900	351,168	17,318,896
EMP4	3,188,788	2,177,052	1,635,223	5,128,343	381,500	2,616,500	142,500	205,000	16,227,549
EMP5	3,931,580	2,167,440	3,271,656	1,655,699	514,251	2,219,907	40,300	2,632,698	16,633,535
All strata	$12,839,249	$6,379,926	$8,584,204	$13,147,102	$1,977,176	$11,442,328	$2,254,176	$3,766,221	$60,390,382

Table 8.—Purchases and sales of dimension stock within survey region

Area	Purchases	Percent of total	Sales	Percent of total
		Pct.		*Pct.*
Alabama	$ 1,461,000	2.65	$ 650,900	1.18
Arkansas	9,739,500	17.67	9,469,500	17.19
Florida	688,300	1.24	718,300	1.30
Georgia	2,092,500	3.80	2,246,000	4.08
Kentucky	1,954,400	3.55	1,413,200	2.57
Maryland	1,022,000	1.85	695,700	1.26
Mississippi	8,038,100	14.59	8,183,200	14.85
North Carolina	13,629,000	24.74	13,757,800	24.97
South Carolina	2,790,900	5.07	792,700	1.44
Tennessee	2,372,300	4.31	7,004,600	12.71
Texas	3,293,900	5.98	1,238,200	2.25
Virginia	7,415,800	13.46	5,257,500	9.54
All other[1]	596,900	1.09	3,667,000	6.66
Total	$55,094,600	—	$55,094,600	—
South Atlantic Region	$27,776,800	50.42	$25,165,300	45.67
East South Central Region	13,825,800	25.09	17,251,900	23.02
West South Central Region	13,492,000	24.49	12,677,400	31.31

[1] This area includes the states of Delaware, Louisiana, Oklahoma, and West Virginia, which were combined to avoid disclosure of purchases and sales by individual firms.

Table 9.—Types of furniture produced, by single product manufacturers

Stratum	ULR	NLR	DIN	BER	RTV	KIT	JUV	OUT	CRH	MAT	OFF	OTH	Total
1	37	4	3	4	1	27	1	1	4	0	1	22	105
2	18	1	1	0	0	6	2	0	4	0	1	4	37
3	18	2	1	7	3	1	0	0	3	0	1	4	40
4	2	0	2	4	0	1	0	0	0	0	0	2	11
5	0	0	0	0	1	1	0	0	0	0	0	0	2
6	9	2	0	2	0	10	0	1	5	1	1	8	39
7	8	2	3	1	0	0	2	0	4	0	0	2	22
8	6	1	1	1	1	1	1	0	1	0	0	3	16
9	4	1	0	4	0	1	0	0	1	0	0	1	12
10	1	0	0	0	1	0	0	0	0	0	0	0	2
11	13	2	2	2	1	11	1	2	6	2	1	12	55
12	6	1	2	1	0	3	0	0	3	0	0	1	17
13	3	0	2	1	0	0	0	1	3	0	0	2	12
14	0	0	0	1	0	1	0	0	0	0	0	0	2
15	0	0	0	1	2	0	0	0	0	0	0	0	3
R1	75	7	7	15	5	36	3	1	11	0	3	32	195
R2	28	6	4	8	2	12	3	1	11	1	1	14	91
R3	22	3	6	6	3	15	1	3	12	2	1	15	89
EMP1	59	8	5	8	2	48	2	4	15	3	3	42	199
EMP2	32	4	6	2	0	9	4	0	11	0	1	7	76
EMP3	27	3	4	9	4	2	1	1	7	0	1	9	68
EMP4	6	1	2	9	0	3	0	0	1	0	0	3	25
EMP5	1	0	0	1	4	1	0	0	0	0	0	0	7
All strata	125	16	17	29	10	63	7	5	34	3	5	61	375

ULR = Upholstered living room
NLR = Non upholstered living room
DIN = Dining room
BER = Bedroom
RTV = Radio - TV cabinets
KIT = Kitchen cabinets
JUV = Juvenile
OUT = Outdoor & recreational
CRH = Church & institutional
MAT = Mattress & bedsprings
OFF = Office
OTH = Other

Table 10.—Plans for within-plant manufacture of dimension parts

Employee size class	Increase		Decrease		Stabilize	
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
1	68	47.8	9	6.4	65	45.8
2	26	41.9	9	14.6	27	43.5
3	28	40.5	11	15.9	30	43.5
4	13	38.3	4	11.7	17	50.0
5	12	31.5	2	5.3	24	63.2
R1	83	42.1	20	10.1	94	47.8
R2	27	36.0	10	13.3	38	50.7
R3	37	50.7	5	6.8	31	42.5
Stratum						
1	40	48.2	4	4.8	39	47.0
2	13	41.9	5	16.1	13	41.9
3	18	40.9	7	15.9	19	43.2
4	6	46.2	2	15.4	5	38.5
5	6	37.5	2	12.5	18	50.0
6	9	42.9	2	9.5	10	47.6
7	7	38.9	3	16.7	8	44.4
8	4	23.5	4	23.5	9	52.9
9	3	25.0	1	8.3	8	66.7
10	4	57.1	0	.0	3	42.9
11	19	50.0	3	7.9	16	42.1
12	6	46.2	1	7.7	6	46.2
13	6	75.0	0	.0	2	25.0
14	4	44.4	1	11.1	4	44.4
15	2	40.0	0	.0	3	60.0
All classes	147	42.6	35	10.2	163	47.2

Table 11.—Firms planning to purchase hardwood parts

Stratum	Yes		No		Don't know		No response	Total respondents
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*No.*
1	4	5.4	40	54.1	30	40.5	12	86
2	2	10.0	13	65.0	5	25.0	3	23
3	1	10.0	7	70.0	2	20.0	3	13
4	1	10.0	5	50.0	4	40.0	1	11
5	0	0.0	2	66.7	1	33.3	2	5
6	1	3.0	23	69.7	9	27.3	6	39
7	1	8.3	5	41.7	6	50.0	0	12
8	0	.0	4	80.0	1	20.0	1	6
9	0	.0	2	66.7	1	33.3	0	3
10	0	.0	0	.0	0	.0	0	0
11	2	5.3	27	71.1	9	23.6	5	43
12	0	.0	6	100.0	0	.0	1	7
13	1	14.3	5	71.4	1	14.3	0	7
14	0	.0	0	.0	0	.0	0	0
15	0	.0	1	100.0	0	.0	0	1
R1	8	6.8	67	57.3	42	35.9	21	138
R2	2	3.8	34	64.1	17	32.1	7	60
R3	3	5.8	39	75.0	10	19.2	6	58
EMP1	7	4.8	90	62.1	48	33.1	23	168
EMP2	3	7.9	24	63.2	11	28.9	4	42
EMP3	2	9.1	16	72.7	4	18.2	4	26
EMP4	1	7.7	7	53.8	5	38.5	1	14
EMP5	0	.0	3	75.0	1	25.0	2	6
All strata	13	5.9	140	63.0	69	31.1	34	256

Table 12.—Frequency of use of hardwood parts (for specific type of furniture)

Stratum	ULR	NLR	DIN	BED	RTV	KIT	JUV	OUT	CRH	MAT	OFF	OTH	Total responses
1	35	12	13	10	6	21	1	0	9	0	9	19	135
2	19	1	4	2	0	2	2	0	2	1	2	5	40
3	18	7	13	16	3	1	0	0	5	0	3	3	69
4	1	0	6	8	0	1	0	0	0	0	0	1	17
5	5	2	11	13	0	0	1	0	0	0	0	2	34
6	4	3	3	4	0	4	0	0	5	0	2	8	33
7	7	0	4	2	0	1	2	0	4	0	1	2	23
8	6	2	4	2	1	1	2	0	0	0	0	4	22
9	4	0	1	5	0	1	0	0	1	0	0	1	13
10	4	0	2	3	2	0	0	0	0	1	1	1	14
11	15	5	4	5	3	9	1	4	11	0	5	4	66
12	5	3	2	1	0	3	1	2	0	0	0	1	18
13	4	0	3	2	0	0	0	0	0	1	0	2	12
14	3	3	3	4	0	1	0	0	1	0	1	1	17
15	2	2	2	2	2	0	0	0	1	0	1	1	13
R1	78	22	47	49	9	25	4	0	16	1	14	30	295
R2	25	5	14	16	3	7	4	0	10	1	4	16	105
R3	29	13	14	14	5	13	2	6	13	1	7	9	126
EMP1	54	20	20	19	9	34	2	4	25	0	16	31	234
EMP2	31	4	10	5	0	6	5	2	6	1	3	8	81
EMP3	28	9	20	20	4	2	2	0	5	1	3	9	103
EMP4	8	3	10	17	0	3	0	0	2	0	1	3	47
EMP5	11	4	15	18	4	0	1	0	1	1	2	4	61
All strata	132	40	75	79	17	45	10	6	39	3	25	55	526

ULR = Upholstered living room
NLR = Non upholstered living room
DIN = Dining room
BER = Bedroom
RTV = Radio - TV cabinets
KIT = Kitchen cabinets
JUV = Juvenile
OUT = Outdoor & recreational
CRH = Church & institutional
MAT = Mattress & bedsprings
OFF = Office
OTH = Other

Table 13.—Response frequency and rank of reasons for purchasing dimension

Reason[1]	Response frequency within each grade							No response	Total response	Rank method 2	Rank method 3	Overall order of importance
	1	2	3	4	5	6	7	8	9	10	11	12
1	127	53	15	3	3	1	0	130	202	3.8	2.5	1
2	123	43	16	7	1	3	0	139	193	4.3	2.7	2
3	25	34	35	20	8	2	0	208	124	6.0	7.1	4
4	30	38	34	15	7	1	0	207	125	5.9	6.6	3
5	35	19	20	20	20	1	0	217	115	6.2	8.0	5
6	14	12	11	7	10	17	1	260	72	7.0	16.5	7
7	61	8	4	2	1	1	1	252	80	6.5	6.3	6

[1] *Reason*

1. Furniture production capacity can be increased with little additional capital investment.
2. Premanufactured hardwood parts can be purchased for less cost than we can produce them.
3. Less space is needed for material inventory.
4. Allows better control of production costs.
5. Manufacturing waste is reduced.
6. Lumber transportation costs are reduced.
7. Other.

Table 14.—Response frequency and rank of factors influencing purchase of dimension

Factor[1]	Response frequency[2] within each grade									No response	Total response	Rank method 2	Rank method 3	Overall order of importance
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	93	28	19	10	10	9	5	6	2	150	182	5.9	4.5	3
2	63	38	38	19	17	8	7	11	4	127	205	5.7	5.0	4
3	15	18	26	23	20	13	20	5	3	189	143	7.5	9.8	6
4	56	65	54	42	7	15	3	1	0	89	243	4.7	3.8	2
5	109	89	49	28	14	4	1	0	0	38	294	3.1	2.5	1
6	35	23	21	18	18	17	12	4	2	182	150	7.1	8.0	5
7	18	20	18	22	18	18	14	8	3	193	139	7.6	10.1	7
8	15	16	11	6	14	10	12	27	7	214	118	8.2	14.2	9
9	25	25	7	6	4	1	4	6	18	236	96	8.3	13.8	8
10	17	6	0	0	0	0	0	0	0	309	23	9.4	18.2	10

[1] *Factors*

1. Species.
2. Supplier's reputation.
3. Lead time required.
4. On-time delivery.
5. Price.
6. Machining tolerances.
7. Moisture content.
8. Allowable amount of defective parts.
9. Grade specifications.
10. Other.

[2] No factor was ranked lower than ninth; therefore the responses are shown only for the first through ninth ranks.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

FORESTS AND FLOODS

in the Eastern United States

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S. C. TECH. & AGR. DIV.

by Howard W. Lull
and Kenneth G. Reinhart

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-226
1972

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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INTRODUCTION

FOR MANY YEARS the beneficial influence of the forest for flood protection has been many things to many people: a dogma of conservationists, a target of engineers, a problem for forest hydrologists, a cornerstone for forest-resource management policy, and a basis for flood-reduction programs.

Despite detractors, a concept that "good" forest cover reduces flood peaks has been warmly espoused by conservationists and accepted by the public. The vehement argument and counter-argument of 50 years ago have subsided, and the controversy has lain relatively quiescent; only recently has the forests' efficiency in flood prevention been openly questioned (*Sartz 1969*).

In the period of most heated discussion, factual knowledge of the subject was strictly limited, and the gap was filled by opinions and deductions destitute of evidence. Beginning in the 1940's and at an increasing rate in more recent years, results from watershed research have helped to clarify the situation.

Also, the wanton exploitation of forest cover that generated both the early forest-conservation movement and untested concepts of beneficial influences of forest cover on floods has largely vanished. Today's forest influences on floods must be evaluated in respect to greatly improved forest protection and cutting practices.

Though research results have been reported in the literature, there has been little or no effort to assemble and collate them; a general review of forest-flood relationships in light

of research results and current forest protection and management is, in our opinion, overdue. This paper is a review of forest-flood relationships in the eastern United States—roughly, the forested regions east of the 100th meridian. Though accumulating knowledge has provided improved understanding, our interpretations, too, may in part be controversial because they controvert certain long-accepted beliefs.

Our purpose is to examine in detail the influence of the present-day forest on flood runoff and sedimentation. Forests and flood discharge will be our dominant concern; sedimentation by and large is a byproduct of their interaction.

This paper was prepared for foresters, conservationists, and others acquainted with the processes and terminology of the hydrologic cycle. It is by no means an exhaustive review of the literature; rather, we describe relationships and introduce concepts that, with minimal reference, seem to us convincingly demonstrated.

EARLY CONTROVERSY

Current attitudes about forest-flood relationships, in this country, have their roots in the history of forest conservation. Around the turn of this century, forest conservationists held the view (shared by many today) that forest-clothed mountains, headwater sources of our major rivers, govern discharge of those rivers. At the same time there was a growing and countrywide concern over past and continuing exploitation of the forest. Those opposing this heedless exploitation seized upon the forest-streamflow relationship as a weapon.

This weapon proved particularly useful during the arguments for the Weeks Law (passed in 1911), which provided for establishment by purchase of National Forests in the East. Purchase was justified by the stated need ". . . for the protection of the watersheds of navigable streams. . . ." At the time, there was no precedent for Federal purchase of timber lands for conservation, but there was no doubt about Federal jurisdiction over interstate commerce and naviga-

tion. The forest-streamflow relationship turned out to be the peg upon which to hang the conservation hat.

This legislative employment of forest influences in the early 1900's aroused opposition that at times became heated. There were extremists on both sides, from those who claimed that the forest had no beneficial effect at all to those who were sure that proper forest conservation promised a solution to the whole flood problem. Most of the claims and counterclaims were simply opinions; the dearth of facts provided little sustenance for either argument or action.

Positions were held with some vehemence, for although there was a lack of knowledge, there was no lack of arguments. Those strongly extolling the beneficial influence of forests in reducing flood peaks were for the most part forest conservationists. Engineers and others on the opposite side of the question were outraged at the conservationists, and were eager to uphold the greater importance and utility of reservoir control of floods, projects in which they were interested or directly concerned.

Recalling this era is of some importance because there are still those who attribute to the forest a greater flood-control potential than it actually has. On the other hand, there are also still those who have little regard for the forest even as a stabilizing influence, an influence that has been well substantiated.

CONSERVATIONISTS' ARGUMENT

Forest conservationists of the early 1900's took the stand that the role of the forest in preventing or reducing floods and in stabilizing the soil was both self-evident and proved by history. Obviously, they claimed, forests hold the soil; their effect on flood peaks is not so apparent, yet the sheer bulk of the forest and the accumulation of its products on the soil must intercept and store significant quantities of

otherwise flood-producing rainfalls. Granting this, the argument continues, the cutting or burning of the forest or its replacement by pasture and cropland will result in greater flood flows, and eventually will transform the land into a desert. Such has been the fate of ancient civilizations; Rome fell because of imprudent removal of forests and waste of the soil (*Marsh 1907*); such can be our fate.

Clapp (*1936*) summed it up:

> It became a part of the forester's philosophy. It became in a real sense an article of faith. On it in part American foresters based their crusade for the preservation and restoration of our forests. Public acceptance of this philosophy has been crystallized into far-reaching legislation both Federal and State.

The philosophy of forest influences ranged widely. Pinchot (*1910*) said: "The connection between forests and rivers is like that between father and son. No forests, no rivers". J. C. Stevens (*1934*) said, with pragmatic skepticism (referring to the Weeks' Law): "Every one loves the forests; every one is glad they are in the hands of the Goverment. . . . If it was necessary once to attribute to them properties they do not possess, in order to 'kid' the people and Congress into doing the thing that everybody wanted done anyway, that necessity has passed. . . . Is there any further necessity to keep up the farce?"

FLOOD CONTROL BY HUMUS

Among the several ways forests were thought to control floods, absorption of rainfall by humus has been the most popular. If the raindrops could be controlled by the forest floor, floods could be prevented, or as Munns and Sims (*1936*) stated: ". . . if each drop of water were held at the place where it first reaches the ground, there would be no floods". Keeping the raindrop on the land would keep it out of the river.

Control of this kind, it was believed, could have an enor-

mous effect. For instance, on 200,000 square miles of the Mississippi River basin to be reforested, the humus layer could be increased by 2 inches, equivalent to an increased water-storage capacity of 232 billion cubic feet, which equals the average flow of the Mississippi at Quincy, Ill., for nearly 37 days; this would not prevent floods but would reduce them (*Sherman 1928b*).

Once in the forest soil, it was believed, the water was under control. George B. Emerson (*1905*) described the retention of rainfall by the deep and spongy mass on the forest floor and its trickling gradually out from this reservoir to form perennial streams.

FLOODS FROM OVERLAND FLOW

The belief that flood runoff from the forests comes from overland flow has permeated forest-flood literature for over 50 years and continues to the present day. Raphael Zon (*1912*) presented a conservative view: when the forest floor becomes completely saturated it allows further rain to pass off just as it would from open ground. The subsurface flow process was not entirely overlooked. Sherman (*1928b*) described how rainfall fills up the interstices and slowly searches out the path of least resistance through the mass of organic debris to reach some spring days or weeks later, rather than in a few hours. What Sherman missed years ago, and what few foresters realize today, is the rapidity with which subsurface flow can move through the forest soil to the stream.

By 1937 Horton was pointing out three stages of thought as to how forests stabilize streamflow (*1937a*). First was the idea that it was due to the sponge-like action of forest litter. When this was recognized as inadequate, conservationists stressed the beneficial effects due to the greater infiltration capacity of forest soils, depression storage, trees breaking

the fall of raindrops, and leaf litter reducing the velocity of overland flow.

The third school of thought was that streamflow may be stabilized if some practical means can be found to increase the infiltration of the soil, cutting down total runoff and increasing groundwater flow (*Horton 1937b*). In retrospect, apparently the infiltration theory was so widely accepted as the mechanism that produced overland flows and floods that foresters overlooked the obvious: most forest floors showed little or no evidence of overland flow, and flood peaks from these areas must come from some other source—namely subsurface runoff.

FLOODS FROM SNOWMELT

The influence of forest cover on retardation of snow melt was acknowledged early. That a delay in melt would result in a corresponding reduction in spring floods was taken for granted. Typical of this thinking is an estimate by Baldwin and Brooks (*1936*) that conifer plantations over a large area could reduce the volume of flood water by 5 percent and flood damages by 10 percent, and that if New Hampshire had been covered with a dense stand of spruce, hemlock, fir, and pine, the flood of March 1936 would have been merely the flood of the decade instead of the great flood of the century.

Even in early years some observers noted that it was not quite that simple, that delay of snowmelt could either reduce or increase peaks. Kellogg (*1908*) quoted one man's opinion that forests are really responsible for floods; snow collects in the forest during the winter and then melts and goes out all at once in the spring; and that makes the floods.

Sherman (*1928a*) recognized the same phenomenon but depreciated its importance. He acknowledged that, if under some conditions the forest had been cleared away, the winter's snowfall would have been dissipated and the resulting

flood would be lower in stage and of very brief duration. In his judgment, this situation was the rare exception.

"WITHOUT THE FOREST . . ."

Throughout the early literature, and even in the writings of today, is a constantly recurring theme: without forest cover, floods would be much worse. Raphael Zon (*1912*) acknowledged that floods produced by exceptional meteorological conditions cannot be prevented by forests; but without their mitigating influence, the floods are more severe and destructive.

Hursh (*1943*) years later expressed the same thought:

> The real consideration is not that storm runoff sometimes occurs from forest land, but rather what would be the relatively much greater runoff from the area under any other type of land use than forest? . . . visualize the catastrophic results of removing the vegetation and attempting to use the land otherwise.

Forests (400 million acres in the East) in this context are regarded as an ephemeral part of the landscape that might be readily removed and replaced by other land uses.

Even many years ago, some people recognized that cutting the forest does not necessarily destroy the forest influence. Chittenden (*1909*) of the U.S. Army Corps of Engineers wrote:

> Soil erosion does not result from forest cutting in itself, but from cultivation. . . . The natural growth which follows the destruction of a forest is fully as effective in preventing erosion, and even in retaining runoff, as the natural forest.

Lowdermilk (*1950*) similarly concluded 41 years later that the cutting of forests does not necessarily destroy forest conditions; the condition of the soil is the final criterion of injurious treatment of a forest in its effects upon run-off.

Hawley, who for many years managed a water-utility forest during a period when such management was a rarity, noted that, under a sustained-yield program, forest cutting does little harm to water and soil (*Hawley and others 1940*):

> Forest devastation is practically unknown in New England. Present cutting methods maintain the forest cover in condition to function efficiently in protecting watersheds and in preventing erosion. . . . There is no evidence to show that methods of cutting the forests in New England used during the last eighty years have injuriously affected any phase of the water problem.

FORESTS AND RESERVOIRS

Zon (*1912*) early recognized that forests alone cannot be depended upon to prevent the occurrence of exceptional floods and that engineering works are necessary. Years later Clapp (*1936*) was to state that no one expects to solve the entire flood-erosion problem with forests; if the forests along with other measures could help to reduce flood heights they would unquestionably serve a very useful public service. Munns and Sims (*1936*) spelled out a division of labor: though foresters contend that measures on the land are as important as measures in the river, there should be no conflict between foresters and engineers; work on the rivers is primarily the function of the engineers, and work on the land is the function of the agriculturalist and forester.

Two years later, the U.S. Department of Agriculture (*1938*) warned:

> There is grave danger that too much may be expected from watershed-protection measures. In the past extravagant claims made by proponents of vegetal controls provoked equally extravagant rebuttals from the proponents of the "structures only" school of thought. . . . It should be clearly understood that watershed-protective measures can never supplant control works along major streams so long as flood plains are occupied, sometimes in defiance to the normal nature of streams. For floods occur even under primeval conditions.

STATING THE CASE FOR FOREST CONSERVATION

Occasionally in the midst of the debate there have been earnest suggestions that forest conservation does not have to be based so heavily on flood-control benefits, but can rest on its obvious assets of timber production, soil conservation, and recreation potential. Abel Wolman (*1937*) believed that the case for soil conservation and reforestation is good by itself and wondered why it should be ruined on the rocks of overstatement, overpromise, or underevaluation of scientific principles.

Moore (*1910*), Chief of the Weather Bureau, opposing exaggerated claims as to the forest's effect on floods, put it succinctly:

> . . . I believe that forests should be preserved for themselves alone, or not at all.

—a remark equalled only by that of Herbert Hoover some years later (*Pack 1927*):

> The floods of the Mississippi . . . cannot wait for trees to grow up even if they were a contributory remedy. But in any event, *I am for trees.*

RESEARCH BEGINS

By the early 1930's, the growing need to obtain facts about the forests' influence on streamflow (including floods, water yield, low flows, and erosion) was recognized. Watershed research was begun at the San Dimas Experimental Forest in southern California, the Sierra Ancha Experimental Forest in Arizona, and the Coweeta Hydrologic Laboratory in western North Carolina. At Coweeta, studies were started to determine the influence on streamflow of clearcutting and regrowth, of clearcutting followed by annual cutting of regrowth, and of clearcutting with conversion to mountain farming. From these studies came the first clear scientific evidence (*Hoover 1945a*) that clearcutting without disturb-

ing the forest floor does not have a major effect on peak flows. Conversion of a forested watershed to a mountain farm, on the other hand, greatly increased peak flows and erosion after a period of years.

Twenty years later, by the 1950's, watershed-management research divisions had been established at all Forest Service experiment stations. By the 1960's the number of forested experimental watersheds under study reached 150. By 1970 almost 2,000 papers had been published describing results. In addition, courses in forest influences, forest hydrology, or forest watershed management are offered at 25 of the 32 accredited forestry schools (*Sopper 1970*), two textbooks have been produced, and an international symposium has been held on forest hydrology.

FLOOD-CONTROL LEGISLATION

Before forest-influences research was well initiated, however, the Omnibus Flood Control Act of 1936 was passed, and the Forest Service was given responsibility for conducting flood-control surveys on forested watersheds to determine the measures required for runoff and water-flow retardation and soil-erosion prevention; the Soil Conservation Service had similar responsibilities on other watersheds. Where estimated benefits of flood control exceeded costs, action programs were planned. Thus foresters were suddenly forced to quantify the forest influence on floods. With factual data in short supply, the recently formulated infiltration theory and the concurrent interest in humus were adopted, and a system intended to determine the flood potential of forest lands and their capacity for improvement was devised. Some of the procedure has been described by Storey and others (*1964*).

Under this Act, studies of 600 watersheds across the country were authorized, preliminary examinations were conducted on 164, full survey reports were completed on 18,

and 11 were authorized for works of improvement. Only two of these (the Potomac and the Yazoo-Tallahatchie in Mississippi) included any substantial program on forest lands in the East.

There was much dissatisfaction with progress under the 1936 Act. Many apparently felt that flood relief through land-treatment measures alone was too little and too slow. This led in 1954 to the passage of Public Law 566, which authorized the Department of Agriculture to construct engineering works in addition to land-treatment measures on watersheds of less than 250,000 acres. The significance of this was not missed by the Corps of Engineers (*U.S. Senate Select Committee 1960*). It hailed this law as the final abandonment of the idea that substantial floods could be significantly reduced by land treatment measures and recognition by the Department of Agriculture that engineering works are necessary even on small streams; flood-control effects of land-treatment measures are considered incidental to their primary purpose of conserving the soil and improving agricultural efficiency.

Flood-control surveys to determine forest-treatment measures were continued in watersheds under P.L. 566. Study and planning have been authorized for about 1,500 small watersheds under this law.

Forest and flood analyses are also a part of the River Basin Surveys authorized by the Flood Control Act of 1950. These Surveys are interagency efforts under the leadership of the Corps of Engineers, and they present a general inventory of possible future developments in the region after consideration of all aspects of the resource problem. The possible economic and other contributions of the forest to the welfare of the region, as well as its flood-control benefit, are considered. Under the Water Resources Planning Act of 1965, river basin commissions of the Water Resources Council are now undertaking comprehensive and coordinated joint planning (*Water Resources Council 1968*).

FORESTS AND FLOODS

FLOODS ARE among the most damaging of all catastrophes. According to one source, potential annual damage in the United States is $1.7 billion (*Water Resources Council 1968*). In comparison, forest fires and forest insects can each destroy about $200 million worth of timber annually, and forest diseases $500 million. (Based on losses reported by the USDA Forest Service (*1958*) and a mean stumpage value of $25 per thousand board feet.) Household fires do $1.5 billion damage annually. Only such devastators as automobile accidents ($11 billion annually), and the current war ($24 billion annually) are more costly.

Flood damages increase steadily. In 1957, for instance, the loss was double that of 1936 despite the fact that during the 1936-57 period $4 billion were spent to prevent flood losses. Increasing losses have been charged to more frequent flooding, rise in property values, and the greater occupancy of flood-prone lands. ". . . there was no flood problem until the white man began to settle in the river valleys. . . ." (*U.S. Senate Select Committee 1960*).

Forests, which occupy the major part of upland watersheds, are associated principally with flood damage in tributary streams. Estimates of the proportion of total flood damage incurred in upland watersheds have ranged from 40 percent (*U.S. Senate Select Committee 1960*) to 56 percent (*Ford and others 1955*). The Federal government has appropriated about $63 for flood control on main streams to every dollar for upstream watershed flood prevention (*Ford and others 1955*).

Annual flood damage in the East, both with and without Corps of Engineers reservoir flood-control projects (constructed and authorized), has been estimated as follows (*Hoyt and Langbein 1955*) in millions of dollars:

Damage area	*Potential damage, without reservoirs*	*Predicted damage, with reservoirs*
New England	19	6
North Atlantic	34	17
South Atlantic	32	18
Ohio Basin	97	19
Great Lakes	6	2
Upper Mississippi Valley	65	42
	253	104

Reservoirs can prevent over one-half of the total potential damage. The remainder could be reduced in part, presumably to the extent that more intensive land treatment for flood control is effected—especially in headwater areas above reservoirs. More than one-half of this land is forested.

FLOOD SEASONS AND SOURCES

Floods in the eastern forest region stem from convectional and cyclonic rainfalls and, in the more northern states, from melting snow and ice jams (with or without a contribution from rainfall). Floods can occur any time of year. In the northern forest their frequency is low during the winter snowpack period and high in the spring.

Precipitation is usually well distributed throughout the year. Excessive precipitation in both summer and winter has caused major floods. Incidence of severe convectional storms is highest in summer and in the interior parts of the region where a continental climate prevails; convectional storms usually flood tributaries only. Flood-producing rainfalls are greatest in the South. The standard project storm, for areas of 200 square miles, increases steadily from 9 inches in Maine to 20 inches in Florida. This is considered to be the

most severe flood-producing rainfall reasonably characteristic of the region for seasons in which snowmelt is not a major consideration (*U.S. Dep. Army 1965*).

Actual flood-producing rainfalls over large river basins are, of course, much smaller than standard project storms. For example, over the Delaware River basin (standard project storms of 9 to 11 inches), average rainfalls for the great floods of record together with the maximum point values (*U.S. Army Engineers 1960*) were as follows:

Date of storm	*Average precipitation over basin (inches)*	*Maximum point value (inches)*
Oct 1903	6.2	10.2
Aug 1933	6.9	16.0
Jul 1935	3.7	10.3
Sep 1938	6.0	9.6
May 1942	2.9	8.6
Aug 1955	4.5	11.1

These rainfalls, though far less than estimated maxima, produced major floods indicating that they greatly exceeded soil-moisture storage opportunities, i.e., the available soil-moisture storage capacity just prior to precipitation.

Heavily forested mountainous areas receive greatest amounts of precipitation. For instance, mean annual precipitation for major mountain ranges and adjacent lands are—from isohyetal map of normal annual total precipitation (*U.S. Dep. Commerce 1968*):

Region	*Mountainous (inches)*	*Adjacent land (inches)*
White Mountains	48 to 74	40 to 44
Adirondacks	44 to 52	36 to 40
Allegheny Mountains	48 to 56	40 to 44
Southern Appalachians	52 to 80	44 to 48

The 16 million acres of forested mountains here considered are headwater sources of several major river systems.

Coupled with the greater amount of rainfall received by most forested areas is their limited opportunity for soil-moisture storage, characteristic of much of the eastern up-

land forest most of the time. Forests predominate where rainfall is frequent, and where soil moisture is high in nearly all months of the year (*Thornthwaite and Mather 1955*). The forest soil is wet most of the time. Soil-moisture storage is also limited by the shallowness of the soils often occupied by forests.

Storage opportunity may be far from adequate: during outstanding storms in the Northeast the net difference between rainfall and runoff is so small that one author said the task of the hydrologist "is one largely of reshaping up a pluviograph of the total precipitation into a 100 percent hydrograph of runoff". Total amount of natural storage may be no more than 1.5 to 2.5 inches (*Hoyt 1942*). Limited storage accounts for the rapid rises in streamflow that come from completely forested watersheds in the White Mountains. Concerning these, Hoyt, describing a record peak flow from the East Branch of the Pemigewasset River, wrote:

> . . . it is perhaps somewhat ironic that the maximum flood runoff of record in the broad area between Maine and Maryland should have occurred in a rugged, forested drainage basin in which . . . there is but little cultivation and which generally has not been greatly modified by man's activities.

He then pointed out that the small amount of natural storage makes difficult the task of those who would materially change flood-characteristics by measures other than large engineering structures.

Substantial amounts of rain, rain and snowmelt, or snowmelt coupled with little opportunity for storage in the soil can generate 8 to 20 inches of flood runoff. In the Northeast, outstanding floods have been associated with runoff of 8 to 15 inches from intensive summer rainfall, following an abnormally rainy period, and with runoff of 10 to 15 inches from rain and melting snow. In March 1963 rainfall plus a snowmelt of 5 to 10 inches totalled as much as 20 inches over large areas and runoff ranged from 70 to 90 percent. Floods from rain and snowmelt are common in the Ohio River basin. The entire basin, lying as it does in the paths

of cyclonic storms from the West and from the Gulf, often receives excessive precipitation when snow is on the ground.

Floods from snowmelt alone are rare, but they can occur. The flood of April 1938 in the deep snow country of the western Adirondacks was caused soley by delayed thaw of a heavy snow cover; after a 30-day period when temperature averaged 24°F., the temperature rose to the middle 70's and remained high for 5 days and produced the highest flood of record on the Black River (*Hoyt and Langbein 1955*).

Floods from late summer or fall hurricane rains have caused extensive damage in Florida, Georgia, and the Carolinas. They sometimes also strike the Northeast; the most damage resulted from two week-apart hurricanes in 1955. Rainfall from Hurricane Connie saturated the soil, priming it for the next week's Hurricane Diane, which deposited record rainfall in eastern Pennsylvania, New York, and southern New England. Consequently, runoff from Diane was much greater than would have been normally expected.

Erosion and sedimentation will be discussed in detail later. We must recognize here, however, that sediment stemming from erosion bulks flood flows and may slightly increase stages. More important, sediment deposits in stream channels reduce the carrying capacity and raise the frequency and severity of over-bank flooding. Also, dirty flood water is more damaging than relatively clean water, and sediment left by a flood can be a substantial part of total damages. It follows then that as forest cover inhibits erosion, it contributes significantly to reduction in flood damages.

HYDROLOGIC PROCESSES: THE MATURE FOREST

The forest influence, whatever its magnitude, is expressed by the manner in which the forest receives, stores, and releases potential flood-producing rainfall. Our initial exposition will be limited to long-established forests that have been protected from burning and grazing. Five hydrologic processes that govern disposition of flood-producing precipitation will be considered: interception, infiltration, soil-moisture storage, overland and subsurface flows, and peak flows. Later, the influence of different forest conditions on floods will be discussed again in reference to hydrologic processes.

A relatively new—and promising—approach to study the disposition of storm rainfall is provided by the variable-area concept (*SE. Forest Exp. Sta. 1962*). This postulates that the stormflow-producing area of a watershed increases with the size of storm and is roughly equal to or somewhat larger than the percentage of precipitation that appears as stormflow. A recent analysis by Ragan (*1968*) of precipitation and runoff of a small forested watershed shows that only a small area contributed flow to the storm hydrograph. The contributing area, a function of the storm duration and intensity, was not uniformly distributed along the channel, but rather was localized in zones of intense contribution. During periods of low intensity most of the flow came from channel precipitation and rain falling on wet areas around seeps. With high-intensity rainfall, flow developed through the forest litter on the hillsides, thereby creating a larger contributing area.

From a major flood event in a relatively shallow-soil area—as in much of the forested mountains—most of an afflicted watershed would contribute stormflow. For a lesser storm event or where soil-storage opportunities are greater—as in the Piedmont and Coastal Plains of the Southeast—the con-

tributing area would be smaller. In either case, the hydrologic processes discussed here would still be active and influential. When the area contributing to floods is but a small fraction of a forested watershed, this accentuates the importance of the forest influence of that portion.

Interception

The forests' initial influence on a flood-producing rainfall is the amount intercepted and stored in the canopy. This is not a major influence. Interception is most effective for small storms, and its effectiveness dwindles rapidly with increased storm size. Hardwoods in full leaf can intercept almost all of a 0.05-inch rainfall, perhaps 60 percent of a 0.10-inch, 12 percent of a 0.5-inch, and 8 percent of a 2-inch storm. Comparable values for the dormant season are 40, 20, 12, and 4 percent—all based on Helvey and Patric's (*1965*) equations.

White pine intercepts greater amounts. White pine plantations 10, 35, and 60 years old will intercept from a 2-inch rainfall 0.17, 0.23, and 0.34 inch, whereas mature eastern hardwoods in the growing season will intercept 0.15 inch and in the dormant season 0.07 inch (*Helvey and Patric 1965; Helvey 1967*). From the growing-season storm the 60-year-old pines would intercept 0.19 inch more rainfall than the hardwoods, in the dormant season 0.27 inch more.

On the other hand, no difference in growing-season interception was found between a 30- to 50-year-old hardwood stand and a 20-year-old red pine stand: red pines and hardwoods each intercepted 0.23 inch from a 2-inch rainfall (*Rogerson and Byrnes 1968*). Similar amounts (about 0.32 inch in the growing season and 0.22 inch in the dormant season) were intercepted from a 2-inch rainfall by a shortleaf pine-hardwood stand in Arkansas (*Lawson 1967*).

There are few data on interception of flood-producing rainfalls. Very likely little more would be intercepted than from the 2-inch storms. Interception will, of course, reduce the amount of flood-producing rainfall that reaches the

stream; but, as Hoover (*1962*) noted, ". . . when it is remembered that most land areas have some type of plant growth similar to tree foliage, which intercepts rain, it is doubtful whether canopy interception by forests is of significance in reducing flood peaks."

The importance of interception to flood peaks is further minimized by the time at which intercepted water is withheld from the hydrograph. Anyone who has sought refuge under a tree at the start of a shower knows that interception claims most of its share at the very beginning of the storm event. Interception affects the initial stages of the hydrograph much more than the later stages, when damaging peaks are likely to occur.

Infiltration

Reams have been written about infiltration and the influence of the forest upon it. Here it is considered to be the process in which water passes through the surface layer of the soil. Where infiltration is limited, overland flow and erosion result. The undistrubed forest floor, common to the forest, is good evidence that overland flow does not occur and therefore that infiltration rates exceed rainfall intensities. In this situation, infiltration is not limiting, and overland flow is not a contributor to flood peaks except where logging, woodland grazing, or burning have removed the litter and humus and exposed the mineral soil.

The prima facie evidence of the undisturbed forest floor can be supported, if need be, by ring infiltrometer and percolation measurements. Infiltration rates over 50 inches per hour have been measured in hardwood stands of West Virginia (*Hornbeck and Reinhart 1964*), and 14 to 50 inches per hour in hardwood and conifer stands in New Hampshire (*Trimble, Sartz, and Pierce 1958*). Oak-pine woodland growing on the deep sandy soils of coastal New Jersey absorbed 56 inches of waste water, from a food-processing plant, sprayed at the rate of 6.3 inches per hour (nearby cropland became saturated and swampy to plow-depth after only 2

inches of water had been applied) (*Thornthwaite 1951*). Percolation tests on cores of humus and A-horizon layers from 29 undisturbed forest areas in Pennsylvania gave rates for mor humus of 236 inches per hour, for mulls and A_1 horizon 63 and 132 inches per hour, and in the lower A horizon 8 to 17 inches per hour (*Trimble, Hale, and Potter 1951*). These are much greater than the estimated peak (100-year) 30-minute rainfall intensities for the eastern forest region of 3 to 6 inches per hour (*Hershfield 1961*).

Infiltration capacities of forest land not only exceed rainfall intensities; they can in addition absorb overland flow from adjacent agricultural lands. In the driftless area of southern Wisconsin, most runoff from open fields on ridges infiltrates into the forested slopes below and never reaches the valley. Over a 4-year period there were 187 significant storm runoffs at upland gages and only 18 at the valley gages. Overland flow from the upland fields infiltrated into the forest floor and seeped into gully bottoms (*Curtis 1966*).

The essentially undisturbed forest floor so characteristic of forests of all types throughout the East also suggests that their soil differences have little or no influence on infiltration rates. Whether the forest is located on a clay that when bare has a low infiltration rate or on a sand with a high bare-soil rate makes little difference under forest cover. There the rate will exceed rainfall intensities. Hoover (*1950*) pointed out the little difference in pore space relationships of the surface 24 inches between undisturbed forest soils of different series.

Soil-Moisture Storage

The storage characteristics of a watershed largely determine what proportion of a flood-producing rainfall reaches any damage point downstream and the rate of delivery at that point. In its broadest sense, storage includes all aspects of retention and detention from interception, depression storage on the surface, storage in the soil and underlying rock, to storage in the channel. Interception has already

been discussed, and channel storage is for the most part beyond the scope of this paper.

Rainfall or snowmelt that reaches the soil is either retained or detained. Retention storage reduces the precipitation available for streamflow; most of the water in this storage is eventually discharged to the atmosphere. Detention storage slows delivery of precipitation to the stream. Part of this water, as subsurface flow, is released quickly enough to be incorporated in the flood hydrograph; some of it is slowed to the extent that it does not contribute to the flood.

Water held in retention storage, by definition, will not contribute to flood volume. Assessing the effect of detention storage is more difficult—much of it moves through the soil rapidly enough to be part of the flood even though it cannot be identified in the hydrograph. This accounts for the very high flood flows discharged from upland forest watersheds in the absence of appreciable overland flow.

Retention storage capacity varies greatly, especially with soil depth and texture. Though many forest soils are classified as shallow (from 5 or 10 to 20 or 30 inches deep), after prolonged drying they can retain several inches of water. However, when flood rainfall occurs, the amount retained at any one point depends not so much upon storage capacity as upon the amount of drying since the last significant rainfall; i.e., the storage opportunity.

Maximum soil-moisture storage opportunity of a watershed can best be estimated from the difference between storm rainfall, following a prolonged drying period, and storm discharge. In the East the capacity of the soil to retain water rarely exceeds 4.0 or 4.5 inches at the time of major storms (*Hoyt and Langbein 1955*). In the Northeast it is much less: Hoyt (*1942*) estimated it at 1.5 to 2.5 inches. Reinhart (*1964a*), calculating maximum storage on experimental watersheds as the difference between storage-exceeding rainfalls and runoffs following long periods of drying, found values of 4.3 to 4.7 inches in West Virginia, 5.4 inches in Pennsylvania, and a little below 4 inches in New Hampshire.

Differences between rainfall and storage opportunity in a 6-inch flood-producing storm (in the unlikely event that it occurred at a time of maximum storage opportunity) would be proportionately greater because they are residuals: 1.3 to 1.7 inches in West Virginia, 0.6 inch in Pennsylvania, and 2 inches in New Hampshire.

Maximum storage values of 4 to 5 inches include, of course, the storage available in the organic material of the forest floor. With an average humus depth of about 2 inches, its retention storage can amount to about 0.8 inch, or about 15 to 20 percent of the total.

Storage opportunity varies seasonally. After the growing season is over and the soil has been recharged from fall rainfalls, storage opportunity is at a minimum until advent of spring. Frequent growing-season rainfalls can then continue to limit storage. For example, maximum storage opportunities on the Fernow Experimental Forest in West Virginia, as estimated from daily water-budget estimates for 11 growing seasons (April-November) and for two storage capacities, were as follows (Unpublished report of the Northeastern Forest Experiment Station, Parsons, W. Va.; estimates based on computation of potential evapotranspiration, using procedure of Thornthwaite and Mather (*1957*)):

	4-inch capacity (inches)	*10-inch capacity (inches)*
1956 (lowest season)	1.2	1.2
1957 (highest season)	2.9	4.4
Mean of 11 seasons	2.2	3.0

Commonly, storage opportunities are much smaller. Even in the driest season (*1957*), for the 10-inch storage capacity the storage opportunity was above 2.0 inches on only 61 days of the 244-day growing season; the mean for the season was 1.3 inches. The mean storage opportunity in 1956 (a wetter season) was only 0.25 inch. From December to March, the period when most floods in this region occur, storage opportunities were even less.

Farther south, on deeper soils, opportunities for storage

are much greater. In the Piedmont of South Carolina, for instance, daily soil-moisture measurements for 3 years under a 50-year-old shortleaf pine-hardwood stand (*Metz and Douglass 1959*) suggested two soil-moisture seasons: wetter from January to April; and dryer from May to December. The percentage of days by 1-inch storage-opportunity classes were as follows:

Storage opportunity (inches)	*Jan-Apr*	*May-Dec*
0.00	8	—
0.1—1.0	19	—
1.1—2.0	31	3
2.1—3.0	31	1
3.1—4.0	8	10
4.1—5.0	3	21
5.1—6.0	—	21
6.1—7.0	—	37
7.1—8.0	—	7

Assuming random occurrence, we would expect the 13-inch standard project storm for this region, 3 out of 4 times, would have in January to April a storage opportunity of 1.1 to 5.0 inches; in May to December the storage, 2 out of 3 times, would be 5.1 to 8.0 inches. However, random occurrence cannot be expected; a major flood-producing storm is more likely to occur during a generally wet period when antecedent precipitation has been above normal. Also, greater soil-moisture storage opportunity in the Southeast than in the Northeast is largely nullified by the greater magnitude of flood-producing rains in the Southeast.

Although assessing the effect of detention storage is difficult, the lesser flood discharges from the forest, as compared to other land uses, suggest that part of this storage is effective in flood reduction. On the other hand, sizable floods from forest areas (in the absence of overland flow) show that much of this detention is too transitory to be effective. More needs to be learned about the utilization of detention storage, the rate of movement of subsurface flow, and whether or not practicable means can be found to obtain

greater utilization of detention storage, both in surface depressions and in the soil.

Overland and Subsurface Flows

The virtual absence of overland flow in the forest (except those areas where logging, grazing, or fire has exposed the mineral soil) is not readily appreciated though several present-day researchers in forest hydrology have noted it. Some years ago, referring to the Coweeta watersheds, Hoover and Hursh (*1943*) reported:

> Under natural forest-conditions, infiltration-values are well in excess of occurring rainfall-intensities . . . no surface storm-flow other than channel precipitation occurs . . .

More recently, Hewlett and Hibbert (*1967*) pointed out that:

> Virtually all techniques now in general use for estimating flood peaks and volumes are based on the seldom challenged assumption that a quick rise in streamflow proves that rainfall is failing to infiltrate and is running over the surface of the ground to stream channels . . . in the case of forest land we should begin with the assumption that all flow is subsurface flow until there is evidence otherwise.

Muller (*1966*) reported little or no overland flow from conifer plantations on the Allegheny Plateau in New York. Tsukamoto (*1966*) in Japan wrote:

> Surface runoff does not take place on forest watersheds as considered before by many investigators. Streamflow during a storm is composed of subsurface flow and groundwater flow.

In Germany, Hesmer and Feldmann (*1953*) found in infiltration studies no overland flow under high, deciduous forest, spruce, or clearcut spruce. The all-important factors causing runoff were exposure of mineral soil by skidding or fire.

A study in southeastern Alaska may be the clincher: over a 30-day period more than 400 inches of water were sprinkled over a steep brush-covered slope without producing overland flow. About two-thirds reached the channel as

subsurface flow; the remainder was lost to deep seepage or evapotranspiration (*Patric and Swanston 1968*).

Overland flow is largely absent in the forest even under flood-producing rainfall. For instance, field examinations after the flood from Hurricane Diane in August 1955 revealed very little overland flow in the Poconos of Pennsylvania or in New England. Signs of it were found only on slopes above 50 percent, at points where subsurface flow presumably intersected the surface. (G. L. Varney. Some aspects of forest land behavior during the floods of August, 1955. 8 pp. USDA NE. Forest Exp. Sta. 1955.)

Evidence of apparent overland flow, small piles of leaves and twigs and even exposure of the mineral soil, can often be noted in small draws, or in drainageways between microridges. Closer observation will usually show that water infiltrated the upper slope to reappear downslope or in the draw. This results not from limited infiltration capacity but from limited storage and percolation capacity and from channel expansion; no amount of improvement in infiltration at the point where the rain fell will mend the situation.

There are occasional reports of overland flow across a shingle-like cover of hardwood litter (*Pierce 1967; Hoover 1962*). This is a local phenomenon in which the flow infiltrates the soil within a short distance. Whipkey (*1967*) observed several instances of overland flow in a hardwood forest where simulated rainfall was applied at intensities of 5 to 30 inches per hour for periods of 60 to 150 minutes. But he noted:

> When observed, overland flow was generally localized on small sections of the plot—occurring when forest litter was wet and matted, giving a 'shingle effect'. However, this flow never became channelized and soon disappeared at breaks in the litter cover.

Despite the virtual absence of overland flow in forested watersheds, hydrologists have in the past calculated absurdly low watershed infiltration capacities from hydrograph analysis, assuming that the source of storm runoff was overland

flow. Thus Horton (*1937a*) reported an infiltration capacity of around 0.06 inch per hour for forested mountainous watersheds in the Upper Connecticut River Basin. Cook (*1946*) pointed out the fallacy of this:

> When a flood record contains subsurface flow, any infiltration rates or indices derived from it will be too small. They will measure, not the capacity of the surface to infiltrate water, but the capacity of the watershed to retain water under the existing conditions. . . . It is the analysis of records such as thees that has led to the rather widespread notion that under long continuing rains the infiltration capacity of an area approaches zero, even when it has a good cover. Actually, the infiltration rates may remain very high, the controlling factor being the storage capacity of the soils.

Since infiltration is seldom limiting in the forest and overland flow is virtually absent, it follows that storm runoff from forested watersheds comes primarily from the subsurface flow. Much of it moves rapidly through large voids. In layered fine-textured soils, subsurface flow moves primarily through interconnected cracks and channels even before the soil profile is saturated. In coarse-textured soils, water moves downward to bedrock or a fine-textured layer without concentrating and collecting in shallow cracks and channels. Whipkey (*1967*) concluded:

> Depending on the depth to a fine-textured flow-impeding layer, flow from catchment areas having coarse-textured soil is more apt to be of the slow but steady type that supplies streamflow during non-storm periods. Where these coarse-textured soils are found on upper slopes and ridges, it is therefore likely that the entire catchment does not supply runoff during the storm period.

Another explanation for rapid subsurface flow is that, under the very wet conditions prevailing at times of flood, water infiltrated into mid- and lower-slopes causes an almost coincident release of water to the channel at the base of the slope by the process of displacement (*Hewlett and Hibbert 1967*). The time involved is much less than would be necessary for the increment of infiltrated water to percolate through the soil to the channel. Still another mechanism envisages relatively small areas, streamside, providing the

throughflow that contributes so heavily to storm runoff (*Betson 1964*).

Peak Flows

Subsurface flow in the forest can produce substantial peak flows. Hursh (*1943*) reported a peak of 167 csm. for a small, forested, high-elevation watershed in western North Carolina during a low-intensity storm in which infiltration was not limiting. In New Hampshire, peak discharges from two well-forested watersheds of 105 and 39 acres during a 7-inch storm in October 1959 were 451 and 462 csm., respectively; storm runoffs, calculated by the procedure of Hewlett and Hibbert (*1967*), were respectively 76 and 85 percent of the rainfall. From much larger watersheds, 45 to 143 square miles in area, peak flows of 126 to over 300 csm. were registered. (Storm peaks and storm damage of 23-25 October, 1959. Hubbard Brook Experimental Forest and White Mountain National Forest, New Hampshire. USDA NE. Forest Exp. Sta., Durham, N.H.)

Historically, floods from forested watersheds are common. Antedating forest cutting, the flood of 1543 in the lower Mississippi Valley was probably larger than any flood experienced since that time (*U.S. Senate Select Committee 1960*). A maximum flood of record in the Northeast came from a well-forested basin (*Hoyt 1942*). On forested headwater streams of the Watauga River in east Tennessee, runoff rates from mid-August 1940 hurricane rainfall were among the greatest experienced in the eastern United States (*Fry 1941*). Record peaks have been discharged from other well-forested watersheds in the East; the following tabulation gives record peak flows (*Linsley and others 1949*) and percent forest cover for watersheds approximately 25, 100, 500, and 1,000 square-miles in area, of three major eastern drainages:

Stream	Station	Drainage area (mi^2)	Peak flow (csm.)	Forest cover (% of area)
NORTH ATLANTIC SLOPE DRAINAGES				
Ellis River	Jackson, N.H.	28	529	100
Rondout Creek	Lackawack, N.Y.	100	267	80
Rapidan River	Culpepper, Va.	465	125	53
N. Br. Potomac River	Cumberland, Md.	875	102	82
SOUTH ATLANTIC AND EASTERN GULF OF MEXICO DRAINAGES				
Morgan Creek	Chapel Hill, N.C.	27	1110	61
Henry Fork	Henry River, N.C.	80	391	88
Yadkin River	Wilkesboro, N.C.	493	324	90
Rocky River	Norwood, N.C.	1370	113	55
OHIO RIVER BASIN				
Elk Creek	Elk Park, N.C.	42	655	67
Watauga River	Sugar Grove, N.C.	91	560	62
Watauga River	Butler, Tenn.	427	168	64
Cheat River	Rowlesburg, W.Va.	972	129	87

Further, a high-elevation, steep watershed completely forested and without appreciable overland flow can produce greater volumes of stormflow per unit rainfall than many pastures and cultivated areas (*Hewlett and Hibbert 1967*). And in the Northeast, all else being equal, the greater the proportion of watershed forested, the greater the runoff (*Lull and Sopper 1966*). These high runoffs and the others tabulated above do not show a "forest influence" but rather the integrated influence of the forest-occupied environment —such as steeper topography and shallower soils.

Summary

What then would be the disposition of a flood-producing rainfall on a mature forest? To begin with, interception would account for a small portion, perhaps 2 to 3 percent for hardwoods and 3 to 6 percent for white pine, the amounts varying with amounts of rainfall and antecedent wetness. Relative to rainfall amounts, the greater the flood-producing rainfall, the smaller the proportion intercepted.

For areas occupied by forest for a long time and not recently severely burned or grazed (i.e., most of the Eastern forest) infiltration is influenced but little by type or condition of forest cover—infiltration rates are higher than rainfall rates. Storage opportunity depends largely on antecedent drying and drainage. Subsurface flows and peak rates are principally functions of precipitation, topography, and soils.

What, then, is the likelihood of increasing the forests' influence on floods? Beginning with interception, possible gains are small. At the most, converting a mature hardwood stand to mature conifers may increase interception of a flood-producing rainfall by 0.2 to 0.3 inch, a trifling amount in light of the substantial amounts of rainfall involved in flood-producing storms.

As is now clear, there is little opportunity to increase the forests' influence by increasing infiltration capacity. This capacity, as has been noted, is greater in most forest areas than maximum rainfall intensities; for the most part infiltration rate will equal rainfall intensity; and further increases in capacity, as might be possible through intensified forest protection, will have no effect on runoff.

Possibilities of increasing soil-moisture storage capacity are also limited. Creation of greater soil-moisture storage opportunity by fostering accelerated forest growth could perhaps slightly increase rates of evapotranspiration; this might or might not affect storm discharge, depending upon moisture conditions antecedent to the storm; and in any event the effect would be small.

In conclusion, there seems to be little opportunity to increase flood runoff control of most forest stands, those that are neither seriously burned nor grazed. Certainly greater infiltration and soil-moisture storage offer no effective means of retaining flood runoff. To the extent that immature stands intercept less rainfall than mature stands, there may be some rationalization for maintaining flood-source areas in mature timber; but, since the benefit would necessarily be small and other resources must be considered in

the Age of Multiple-Use, this approach can hardly be justified.

Most of our evidence and reasoning, so far, tends to minimize the forests' role in flood-prevention. The reader's response may well then be "But suppose the forest were not there?" Our present assumption is that we are considering a forested site; later we will discuss conditions where the land is under some other form of use or where the forest is cut, burned, or grazed. We can take this opportunity to note, however, that over most of the mountainous eastern, flood-producing area the forest *is* there, a natural part of the landscape with little likelihood of replacement by any other type of cover.

FOREST, FROST, AND SNOW

In the winter of more northern latitudes, the forest influence on frost and snow has been thought to have a major beneficial effect on the amount and timing of flood runoff. Many have believed that concrete frost in the forest increases flood runoff, and shaded accumulations of snow decrease it. The first statement is a misconception; the second requires qualification.

Frost

Concrete frost can prevent infiltration and cause overland flow. For instance, overland flow from concretely frozen soil on open fields was a principal source of runoff in the March 1963 flood near Ithaca, N.Y. (*Spaeth and Diebold 1938*). Frozen soil was limited entirely to bare fields; it did not occur in neighboring woodland or grassland. About 80 percent of the 9 inches of rain and snowmelt ran off two potato fields with a 14-percent slope. From a neighboring forest area of 27-percent slope, there was less than 0.5 percent surface runoff (*Bennett 1937*). At East Lansing, Mich. with

frost penetration to a maximum depth of 30 inches, 4.6 percent of precipitation ran off cropland during the winter of 1943-44; from the woodland watershed there was 0.2-percent runoff (*Garstka 1945*).

From our previous discussion of subsurface flow, it should be obvious that comparisons like these do not tell the whole story. Almost certainly the forest does not retain all of the infiltrated water for very long; much of it can find its way to the stream soon enough to become part of the flood runoff.

The difference in the amount of overland flow lies in the fact that concrete frost occurs only sporadically in the forest. For instance, in the Adirondacks under maximum snow accumulation, concrete frost about 2 inches deep was found at 30 to 40 percent of sampling points in sapling stands and 15 percent in sawtimber; frost tended to concentrate beneath conifer crowns in the snow-interception zone (*Lull and Rushmore 1961*). Konda (*1955*) reported sporadic frost to a depth of 18 cm. under hardwoods in Japan. In a hardwood stand in New Hampshire, characterized by mounds and depressions from windthrow, Hart and others (*1962*) noted sporadic frost and its effect on overland flow as follows:

> The occurrence of concrete frost varied from 23 percent (after a cold period without a snow cover) to none. Throughout most of the winter snow insulates the soil and restricts frost formation. During three winters of frost observations, concrete frost was found at only 4 percent of the 2,800 sampling points. However, 78 percent of these points where frost was found were on mounds where little or no humus had accumulated; the remainder were found on slopes; and no frost was observed in depressions. The average depth of concrete frost on the mounds was 2.7 inches, and on slopes 1.6 inches. It should be noted that any overland flow from a mound having concrete frost would be absorbed by the unfrozen slopes and depressions adjacent to it.

Frost is more prevalent under pine than under hardwoods and still more prevalent in open fields. Percentage frost in 40-year-old pine stands, a 40- to 50-year-old oak stand, and a grassy field near Plymouth, N.H., during maximum occurrences were as follows (*Hart 1963*):

	12 Jan	26 Jan	7 Feb
Field	100	75	54
White pine	93	43	43
Red pine	21	25	14
Hardwood	39	14	14

Frost depths, about 2 inches, were fairly uniform. Here again, except for the 12 January frost in white pine, frost frequency was too low to have any real effect on overland flow.

Nor does concrete frost in the Lake States appear extensive enough to generate any quantities of overland flow. In northern Minnesota, for instance, just before the spring breakup, concrete frost was found on 20 percent of sampled points in a dense balsam fir stand, at no points in aspen and white pine-hardwood stands, and at 50 percent of the points in an open grazing area (*Bay 1958*). In a red pine plantation where concrete frost was found at 76 percent of the points and in open brush at 57 percent, humus descriptions gave no suggestion of disturbance by overland flow (*Bay 1960*), probably because the frost was the porous-concrete type that Stoeckeler and Weitzman (*1960*) found especially prevalent in red pine plantations. In northern lower Michigan, concrete frost was found in 58 percent of a closed red pine plantation under apparently undisturbed pine needles; frost frequency in an open plantation was 14 percent, and in oak and northern hardwoods 5 to 6 percent (*Striffler 1959*). The disastrous floods of 1959 in Ohio were laid to heavy rains on frozen, open ground; no concrete frost was found in the forest (*Wray 1959*).

If significant amounts of overland flow commonly occurred over concretely frozen soil in the forest, litter and humus would be disturbed. There are no known reports of this. Likely, the scarcity of concrete frost in the forest can be accounted for by the insulating effect of humus in latitudes of occasional freezing temperatures, and in the more northern latitudes by the joint insulating effect of humus and accumulated snow, an insulating effect greater than the effects

of equivalent depths of humus or snow (*Thorud and Anderson 1969*).

Snow

Along with the widely held belief that increasing infiltration is the way to stop floods from rainfall, there is a companion idea almost as dubious: delaying snow melt is the way to stop snowmelt floods. The situation is not that simple.

Forest cover intercepts snow. In round figures, hardwoods intercept about 10 percent of snowfall and conifers (red and white pine) about 25 percent. Forest cover also delays snowmelt by shading: in analyzing the sources of flood water from a 3-day rainfall-snowmelt flood in Oregon, Anderson (*1969*) estimated that forest shading reduced the melt rate by 40 percent, reducing flood runoff by 10 percent. These two processes, interception and shading, can serve to reduce flood flows—but not always.

In the 1880's, the Russian scientist Voyeikov noted that spring flood peaks were higher from completely forested watersheds than from fields alternated with forest. During late-spring melting, basins 50 percent forested had two peaks, the first from the field, the second from the forest (*Ivanov 1951*). On the Allegheny Plateau higher flows from the forest were measured in the 1940 spring snowmelt season: from an open watershed the daily discharges from three consecutive 4- to 5-day periods were 0.31, 0.21, and 0.02 inch and for a well-forested watershed 0.07, 0.44, and 0.49 inch. (R. W. Pierce, H. L. Mitchell, and F. F. Tuthill, *Snow Survey Report, Allegheny Watershed,* 15 pp., USDA NE Forest Exp. Sta., Upper Darby, Pa., 1940.)

The most recent and best documented expression that forests, under certain conditions, may increase snowmelt-flood peaks comes from Satterlund and Eschner (*1965*). They concluded that, in the Allegheny Plateau:

> The average rate of concentrated runoff during snowmelt appears to be more rapid following reforestation of open lands, be-

cause runoff from the forest, though reduced in quantity, is even more concentrated in time.

This comes about when open fields are bare of snow and higher-than-usual spring temperatures melt the accumulated snow that still remains under the trees. Thus though interception can reduce the amount of rainfall and snow available for flood runoff, the delay in snowmelt by shading may provide an opportunity for later flood-producing snowmelts under the influence of warmer temperatures likely to occur at later dates.

Clearcutting can have the opposite effect. Thus, clearcutting a small hardwood watershed in New Hampshire increased peak flows in the early part of the snowmelt season by as much as 35 percent, from 59 to 79 csm., and decreased them as much as 66 percent in the later part, from 34 to 12 csm. An extension of this study suggested that clearing as much as 25 percent of a hardwood forested area would not greatly affect the volume of downstream flows during the snowmelt season (*Hornbeck and Pierce 1969*).

FOREST TREATMENT AND FLOOD RUNOFF

If we concede that (in the ungrazed and unburned forest) differences in forest type and condition have little influence on flood flow, what then is the effect of cutting the forest? Of forest fire? Of reforestation? Of woodlot grazing? Again, these effects are exerted and made manifest in the several hydrologic processes.

Harvesting

The forests' influence on floods is a product both of trees, their interception and transpiration, and of the singular characteristic of forest soil, namely its high infiltration capacity. Therefore, for any one harvesting operation, the effect can depend on the proportion of trees cut and the degree the

porous soil is disturbed. Even when all trees are cut, their hydrologic influence is still exerted in part through undisturbed soil.

Interception.—As noted, in the mature forest, interception of rainfall is not a major influence on floods. Thus, any reduction by forest cutting could have little influence. Tops and branches left in the woods continue to intercept some rainfall, with regrowth aiding and abetting. The same cannot be said for snow interception, though its effect also is not a major one. Nevertheless, cutting openings in stands results in greater accumulations of snow. During spring floods this can swell snowmelt peaks.

Infiltration and overland flow.—Infiltration is reduced by forest cutting only to the extent that forest soil is disturbed and compacted; on undisturbed areas infiltration rates remain high. The trees may be cut or killed, but their effects can persist. After the commercial clearcutting on the Fernow experimental watershed, infiltration rates as measured with ring infiltrometers were found to be limiting only in the tread area of bulldozed roads. No appreciable overland flow was observed other than from skidroads (*Reinhart 1964b*). Continued high infiltration rates after clearcutting, with virtual absence of overland flow, have also been observed on experimental watersheds at the Coweeta Hydrologic Laboratory (*Hoover 1945a; Johnson and Kovner 1954*) and at the Hubbard Brook Experimental Forest (*Hornbeck and others 1970*).

Continued high infiltration rates after clearcutting are due in part to the persistence of humus. At the Vinton Furnace Experimental Forest in Ohio, Carmean (*1959*) noted that much of the organic matter remained on the forest floor 4 years after clearcutting a 90-year-old mixed oak stand. Logging slash and rapid growth of herbaceous plants, tree seedlings, and hardwood sprouts furnished much new material. Weights of organic material on cut and uncut plots were not significantly different. Likewise, at the Fernow Experimental Forest in West Virginia, humus depths 6 years

after clearcutting and regrowth were found to be little different from depths measured before clearcutting; if anything the depths had increased.

The enduring hydrologic effect of trees after their demise was well borne out in New Jersey, where spraying of wastewater on a forested area at the rate of 400 to 600 inches a year for 7 years killed most of the trees and undergrowth and replaced them with a rank growth of water-tolerant vegetation (*Little and others 1959*). Infiltration was not restricted. Rates were still high enough to take care of large volumes of water because the forest floor had not been disturbed. Killing the trees did not increase overland flow.

Logging, however, can disturb a considerable area. Generally skidroads take up about 20 percent of an area, but the total area compacted—considering loading sites and trails over which logs are skidded—may run as high as 40 percent. With care in locating roads and trails, this can be reduced to 10 percent. A minimum of roads, however, will ensure the traffic for a well-compacted road.

Soil-moisture storage.—Both capacity and opportunity can be reduced by cutting trees. Capacity is reduced to the extent that accumulations of forest humus are reduced. With rapid regrowth as noted, this can be only a minor effect.

Reduction of transpiration with cutting produces wetter soils with less opportunity for storage of flood-producing rainfalls. For instance, at the Fernow Experimental Forest, the average increase of 21 percent in summer peak flows following clearcutting was attributed principally to insufficient storage opportunity resulting from reduced transpiration (*Reinhart and others 1963*).

Peak flows.—The effect of cutting on flood runoff can be treated most briefly in respect to clearcutting, for if clearcutting has no major effect (which appears to be the case) then less drastic degrees of cutting should be even less effective. The first evidence of this was provided by the Coweeta Hydrologic Laboratory in western North Carolina, where clearcutting a 33-acre area, leaving the trees where they fell,

and annual cutting of sprouts, increased annual runoff by about 11 inches on the average, but did not increase maximum peak discharges during storm periods (*Hoover 1945a; Hewlett and Hibbert 1961*).

More recently at Coweeta, clearcutting a mature hardwood forest on a 108-acre high-elevation watershed increased peak flows by an average of 9 percent and increased stormflow volume of all major storms by an average of 11 percent, or 0.23 inch at the mean storm runoff of 2.1 inches. Greater effects were produced from larger storms: for a 7-day flood sequence the volume of storm runoff increased 22 percent but amounted to less than 1 inch of direct runoff. No overland flow was observed (*Hewlett and Helvey 1970*).

Somewhat similar results were obtained by Reinhart and others (*1963*) in a watershed study of commercial logging in West Virginia. In this instance all timber of commercial value (86 percent of the total volume) was removed from a hardwood-forested watershed. Instantaneous peaks (all far below flood magnitude) during the growing season were increased on the average by 21 percent; in the dormant season they were apparently reduced by 4 percent. Stormflow volumes increased up to a maximum of about ½ inch. Comparable results have been reported from Japan, where clearcutting a 6-acre watershed increased peak runoff from heavy rains about 20 percent (*Maruyama and Inose 1952*). Overland flow was not observed in either of these studies. They and the Coweeta studies indicate again that heavy cutting is possible without serious watershed deterioration as long as the mineral soil is not greatly exposed or compacted. Infiltration capacities are not necessarily reduced.

Reductions in interception and soil-moisture storage opportunity by clearcutting are sufficient to increase storm peaks from high-intensity storms by 10 to 20 percent; and stormflow volumes by ½ to 1 inch, depending upon soil depth, antecedent conditions, and other factors. These increases would be restricted to flood-producing rainfalls that occur during the growing season or recharge period when a period of dry-

ing had established a storage differential between clearcut and forested areas. Otherwise, during the dormant season, and during growing-season periods when soil moisture contents were the same, no greater runoff would be expected from clearcutting. Practical importance of the increase is diminished by the fact that appreciable differences occur only when there is considerable storage opportunity in the uncut forest, and streamflow for a given flood-producing rainfall is necessarily below the maximum at such times.

Lesser cuts would have lesser effects. At Coweeta, cutting a dense laurel-rhododendron understory and cutting riparian vegetation did not increase maximum peak discharges. No overland flows occurred (*Johnson and Kovner 1954*). At the Fernow, diameter-limit and selection cuts that removed 20 to 59 percent of the original stand had no perceptible effect on peak flows (*Reinhart and others 1963*).

These results do not support the commonly-held belief that floods are caused by clearcutting, at least when regrowth is permitted. Reinhart (*1964b*) has commented on this:

> There is little doubt that complete forest destruction . . . does great harm. . . . But a distinction should be made between clearcutting steep lands, followed by conversion to pasture or hillside crops, and clearing without serious soil compaction followed by regrowth. . . . As long as the forest floor remains intact, most of the beneficial effects of the forest, hydrologically speaking, may still be present.

In a recent study at the Hubbard Brook Experimental Forest in New Hampshire, an out-of-the-ordinary treatment —removal of forest and ground cover and prevention of regrowth—was applied; peak flow was considerably increased. For a 39-acre watershed, comparing the six times from June through September in which instantaneous peaks exceeded 0.8 inch per day in the untreated control watershed, the changes were -7, 0, 29, 41, 70, and 211 percent. Variations were due largely to differences in available soil-moisture storage; infiltration apparently was not a limiting factor. Changes in dormant-season high flows not involving snow-

melt were usually negligible, indicating the similarity in soil-moisture regimens (*Pierce and others 1970*).

In a sense, a four-line defense in depth restricts increases in flood peaks and flood runoff after clearcutting. First, as the small-watershed studies plainly indicate, overland flow is not generated where the forest floor is not disturbed; seasonal peak flows and storm runoff increase, on the average, by only about 10 to 20 percent. In the second line, most overland flow from logging roads, landings, and other disturbed areas can be absorbed by infiltration into adjacent areas, especially where logging operations are properly planned and conducted. Third, the increase in peaks and storm runoffs diminishes—probably dropping to negligible amounts within 5 to 10 years—as regrowth re-establishes interception and storage opportunity. Fourth, rarely is more than 1 to 2 percent of any management unit clearcut in any year under a sustained-yield program of forest management; where forest holdings are in many ownerships of limited area, variation in age and condition of the stands limits the amount clearcut at any one time.

This scattering of clearcuttings could not mount a major flood threat. For example, 10 percent of a major forest watershed in various stages of growth after clearcutting under even-aged management might produce 10 percent more unit-area discharge. Given a rainfall that would produce 6 inches of runoff from the uncut area, the increase in runoff from the areas as a whole would be 1 percent, from 6.00 to 6.06 inches. The likelihood that these increases will become synchronized to augment the flood peak is indeed remote because these increases are derived from various parts of the watershed.

Finally, there remains the question about the general trend in forest area. Region-wide, the commercial forest area increased between 1938 and 1962:

	Million acres
1938	344
1948	350
1958	362
1962	373

No overall change is expected by the year 2000, gains by retirement of cropland to forest being offset by diversion of forest to urban and transportation uses (*U.S. Dep. Agr. 1965*). Presumably the mountainous watersheds, largely unsuited to agriculture and urban use, would remain forested; the greater flood potential that would follow forest removal is not likely to be realized.

Burning

The effect of burning on flood peaks depends on the proportion of watershed burned and the intensity of the fire. Theoretically, burning may have a greater effect than harvesting: as noted, clearcutting may well have no major effect on flood peaks because of the protective influence of the forest floor; this protection may be destroyed in a watershed completely burned. Despite the potentially damaging effect of fires, however, their hydrological effect in the main is negligible because of current high levels of fire protection.

Interception.—Most forest fires are of the ground or surface types and have little effect on interception. Crown fires that kill trees can sharply reduce interception until canopy renewal by reforestation or sprout growth.

Infiltration and overland flow.—These may or may not be affected by fire. There is evidence that fire can reduce the infiltration capacity of forest soils. In the Ozark Mountains of Missouri, Arend (*1941*) found that the average infiltration rate was 2.1 inches per hour for unburned plots as compared to 1.3 inches for plots that had been burned annually for 5 or 6 years. Auten, in an earlier Ozark study (*1934*), found an average infiltration rate about 2 to 8 times greater on unburned plots than on burned. Paulsell (*1957*) reported that unburned areas in Missouri absorbed water 4½ times faster than ones that had been subject to seven annual fires.

Other research has shown less notable effects. Burns (*1952*) found that moderate burning on sandy soil in the pine barrens of New Jersey had little effect on infiltration,

increasing the time to infiltrate 1 liter of water only from 140 to 150 seconds. No significant difference in infiltration rates between burned and unburned areas was found in loblolly-shortleaf pine stands in Alabama (*Hodgkins 1957*).

These variable effects must derive from differences in amounts of litter and humus consumed. Frequent fires can remove most of the protective cover, increasing the potential for overland flow. A study in North Carolina has shown that runoffs from a woodland plot burned twice a year at first increased rapidly (*Copley and others 1944*):

Year	*Unburned (inches)*	*Burned (inches)*
1932	0.11	0.16
1933	.07	.12
1934	.04	1.54
1935	.002	4.64
1936	.003	8.30
1937	.01	8.60
1938	.001	9.90
1939	.001	8.98
1940	.001	6.22
Mean	0.03	5.38

After 5 years of burning, the annual runoff from the burned plot levelled off to an average of 22 percent of the rainfall as compared to 0.07 percent from the unburned plot.

In the loessial uplands of Mississippi, Meginnis (*1935*) found that annual burning of a scrub oak forest resulted in overland flow from 54 of 103 rains as compared to 32 from a mature oak forest unburned for at least 7 years. In the 2-year study, less than 1 percent of the rainfall appeared as runoff in the mature oak plot whereas the scrub oak plot produced 8 percent.

Soil-moisture storage capacity.—This can be reduced to the extent humus layers and organic material in the mineral layers are burned. In the upper 2 inches of soil severe burning can reduce the capacity about ¼ inch (*Dyrness and others 1957*). With an overlying 2-inch layer of humus destroyed, the total reduction would be about 1 inch. Crown fires obviously would drastically reduce evapotranspiration

and opportunities for soil-moisture storage; the effect would be similar to cutting the forest.

Peak flows.—The effects of burning on peak flows are often assumed to be destructive and self-evident. But if we judge the seriousness of a problem by the research undertaken to meet it, the effects have not been sufficient to generate concern; there are in the East no watershed studies of the effects of fire on flood peaks.

Plot studies, previously described, point to deleterious effects from repeated burnings, a situation no longer prevalent in any forest region. Annual wildfires are a thing of the past. Prescribed burning in the Atlantic Coastal Plain may come closest to it. Designed to reduce brownspot infection of longleaf pine seedlings, or competition from hardwoods, or fire hazard, it calls for burning every 3 to 10 years (*Smith 1962*). There has been no evidence, however, that this now commonly accepted practice results in any great increase in peak flows.

A substantial reduction in area burned has served to diminish the hydrological importance of fire in the East. From 1931 to 1936 an average of 2.3 million acres of forest land burned annually; from 1961 to 1966 the average was 1.0 million acres (*USDA Forest Service 1967*), or about 0.3 percent of the total forest area. Forest fires, on area alone, cannot be considered a major cause of floods.

Grazing

Woodland grazing has its major effect on infiltration, sharply reducing it and increasing overland flow by soil compaction. Stoeckeler (*1959*) for instance, found the following infiltration rates in ungrazed and grazed oak and conifer stands in Wisconsin:

	Inches/hour
Ungrazed native oak	7.46
Grazed native oak	.05
Ungrazed Scotch pine	11.02
Grazed Scotch pine	1.25

To our knowledge, measured runoff from a grazed hardwood forest has been compared with that from an ungrazed woodland in only three studies, two of which were in Wisconsin. In the first, near LaCrosse, about 8½ percent of the rainfall of eight intense storms appeared as surface runoff on a grazed watershed. On an ungrazed area runoff occurred only twice and then in quantities so small as to be insignificant (*Hays and Atkinson 1939*). A later study at the Coulee Experimental Forest, also near LaCrosse, showed that 3 percent of the precipitation from five major storms appeared as runoff from a heavily grazed woodland, while ungrazed forested watersheds produced no measurable flows. Peak flow from the grazed area was 0.12 inch per hour. (Richard S. Sartz: Effect of land use on the hydrology of small watersheds in southwestern Wisconsin; North Central Forest Experiment Station, LaCrosse, Wisconsin, 1969.)

A more intensive study was carried out at Coweeta, where a 145-acre forested watershed was grazed from May to September for 9 years by an average of six head of cattle. By the end of the first growing season practically all herbaceous forage and much of the hardwood understory had been consumed and supplementary feeding was necessary. By the end of the eighth grazing season, overland flow moved directly into the stream, and there was an immediate sharp increase in frequency and magnitude of peak flows. Before grazing, 2 inches of rainfall (between beginning of runoff and peak runoff) produced a discharge of about 18 csm.; after grazing, the peak was 32 csm. For a 4-inch rainfall, comparable values were 32 and 120 csm. (*Johnson 1952*).

Woodland grazing in the East is not now the problem that it was in the 1930's when the Coweeta study was planned. In the more northern states and in mountainous areas, farmers have found that grazed woodlands can adequately support neither cattle nor trees, as the study at Coweeta suggests; and in those regions woodland grazing decreased sharply between 1930 and 1964 (*U.S. Dep. Commerce 1931, 1967*). The area grazed, in thousands of acres, was:

Region	*1930*	*1964*
New England	3,147	814
Middle Atlantic	3,334	1,407
East North Central	12,547	7,160
South Atlantic	9,067	11,502
East South Central	8,076	9,912
West South Central	20,997	18,096

In seven Southern States (Alabama, Florida, Mississippi, Tennessee, Louisiana, Arkansas, and Kentucky) woodland grazing has been found profitable. Here, beginning in the 1940's, successful programs were developed for coodinating the use of forest range, improved pastures, and other sources of forage and feeds (*Reid and Price 1964*). As a result, woodland grazing in these states increased from 12 million acres in 1940 to 20 million acres in 1964. Slightly over one-half of this increase was in Florida.

Regeneration

Planting open areas—especially to conifers—can sharply reduce peak flows as the trees grow in height, density, and hydrologic influence.

Interception.—Interception by conifers increases sharply with age. As noted earlier, from a 2-inch rainfall, for example, a 10-year-old white pine stand could intercept about 0.17 inch, a 35-year-old stand 0.23 inch, and a 60-year-old stand 0.34 inch, the oldest stand intercepting twice as much as the youngest. Snow interception reduces the potential volume of floodwaters. In the Adirondacks there are about 6 inches of snow-water equivalent in spruce-fir and 8 inches in hardwoods at time of maximum accumulations (*Lull and Rushmore 1960*).

Infiltration and overland flow.—These can change as the plantation matures, the degree of change depending on the infiltration capacity at time of planting. Planting a bare eroding site can in 10 years increase infiltration to the point that overland flow and erosion practically cease.

Soil-moisture storage.—Major increases in detention storage may also follow forest growth. For instance, on an ex-

perimental watershed at Coshocton, Ohio, noncapillary pore space in the 0-to-7-inch layer of idle land, a 20-year-old pine plantation, and protected hardwoods was as follows (*Harrold and others 1962*):

	Idle (% by vol.)	*Pine* (% by vol.)	*Hardwood* (% by vol.)
Keene silt loam	11.4	14.7	16.5
Muskingum silt loam			
Sandstone & shale	14.9	23.4	23.1
Sandstone	21.3	25.2	24.4

In order, the pine plantations on the three sites had 29, 57, and 18 percent more detention storage than the idle land.

Reforestation of old fields, however, may not quickly restore detention storage. In South Carolina's Piedmont, Hoover (*1950*) found detention storage of 4 inches in the upper 24 inches of an undisturbed hardwood-forest soil whereas under an old-field pine stand (25 to 30 years of age) with a sandy plow horizon, detention storage was 1.2 inches; detention storage totaled 17 and 5 percent by volume, respectively. Both forest soils were stabilized.

Peak flows.—Increases in interception, infiltration, and soil-moisture storage concurrent with plantation growth may sharply reduce peak discharges, the reduction varying with, among other things, season of the year, vegetal cover prior to conversion, and proportion of the watershed planted. Results of four studies are given in table 1. The reduction in winter peaks for the New York study was attributed to the lower melt-rate of snow shaded by the conifers; some of this reduction, however, could come from greater soil-moisture storage opportunity provided by increased transpiration the preceding growing season.

Planting the Tennessee watersheds reduced summer peaks by amounts ranging from 62 to 92 percent. The much greater reduction in winter peaks on the Pine Tree Watershed, compared to White Hollow, may be due to its relatively greater area planted and to its smaller size. Interpretation of the Tennessee results is difficult because the treatments included other runoff and erosion-control measures, such as

Table 1.—Effects of planting on peak flows

Watershed location	Area, square miles	Watershed condition		Effect on peak flows
		Before treatment	After treatment	
Shackham Brook near Truxton, N. Y. *(Schneider and Ayer 1961)*	3.12	25% deciduous, 1% coniferous, 74% pasture and crops	27% deciduous, 57% coniferous, 16% pasture and crops	From 1939 to 1957 reduced peak flows by 41%, ranging from 66% in November to 16% in April.
White Hollow Watershed, Mason County, Tenn. *(TVA 1951)*	2.68	66% poorly stocked mixed hardwood and pine, 4% cultivated, 4% grassland, 26% abandoned land	100% mixed hardwood and pine	From 1935-36 to 1942-49 summer peak discharges were reduced from 73 to 92%, dependent on initial soil wetness and rainfall intensity. Winter peaks were reduced about 5%.
Pine Tree Branch Watershed, Henderson County, Tenn. *(TVA 1955)*	0.14	23% deciduous, 9% cultivated, 19% pasture, 47% idle, 2% miscellaneous	33% deciduous, 67% coniferous	From 1941 to 1950 reduced summer peaks by 62 to 87%, dependent on soil wetness and rainfall intensity. Winter peaks were reduced 61 to 82%.
Watershed 172, Coshocton, Ohio *(Harrold and others, 1962)*	0.068	29% woodland, 51% pasture, 20% idle	43% natural woodland, 57% forest plantation (pine and locust)	From 1938 to 1957, average growing season peaks reduced by 59%; dormant season peaks reduced by 69%. (Mean peaks were 35 and 46 csm. in growing and dormant seasons, respectively.) No effect found on peaks from extreme storm occurrences (data insufficient for rigorous analysis).

gully check dams; certainly some of the reduction in peaks was due to these.

Regeneration, especially by conifers, thus offers an effective method of flood reduction. Greater value of planted land also leads to its better protection from fire and grazing, thereby maintaining the flood-control benefits.

Substantial reduction in peak flows from reforestation demonstrates that the forest influence should not be considered by itself alone, but only relative to other land uses. This suggests that the principal opportunity for flood prevention lies in converting abandoned idle land to forest land. In the East there are about 26 million acres of nonstocked commercial forest land for conversion: 15 million in the North and 11 in the South. (*USDA Forest Service 1965*). Much of this area is occupied by brush or other vegetation that may already provide considerable protection against overland flow and transpiration to develop storage opportunity.

Planting considerable areas of open land will not necessarily reduce peaks in regions where periodically above-normal temperatures in the spring rapidly melt snow accumulated under plantations, producing above-normal peak flows. Those areas require the natural desynchronization provided by juxtaposition of open and forested lands such as in the northern Allegheny Plateau of New York (*Satterlund and Eschner 1965*). A mixture of conifer and hardwood areas may also accomplish desynchronization.

MODIFIERS OF FOREST INFLUENCES

The forest's influence on floods will vary under different conditions: it is diminished as storm rainfalls increase; it is greater for small watersheds than large; it is generally less important than physiographic controls; it is by no means comparable to reservoir control; and it is not sufficiently strong to use as a predictor of flood discharges.

Storm Size

From what has gone before, it should be apparent that the forest has a relatively greater influence on stormflow from small storms: interception accounts for a larger proportion of small rainfalls, and the opportunity for soil-moisture storage will subtract a greater proportion from the smaller rainfalls. The forest has less effect, proportionately, on extreme storm events. As Hoyt and Langbein (*1955*) put it: "We know, however, that nation-wide floods seem to roll out of forests as well as off farms". These floods have been described as follows (*Cook 1945*):

> The great floods that inundate the principal valleys (do so much damage to river cities) are caused by general and protracted storms, covering wide areas and precipitating great depths of water. Although the rates of rainfall are usually low, the volume is enormous. As a result of such storms, the soil becomes thoroughly soaked and infiltration capacities reach minimum values. Moreover, the thinner soils become saturated and finally can retain no more water. Under these conditions, every small stream over thousands of square miles flows at or above bank-full stage for many days. The tremendous volumes of water moving down through the tributaries pass into the valley of the main stream, filling it like a great trough into which water is poured from both sides. Runoff causing floods like these is, of course, affected but little by treatment of the land.

There is often a tendency—if not a temptation—to argue that the forest will retain or delay some portion of any rainfall, including the general and protracted storms described above, and that this will to some degree reduce flood runoff and its peak. In a general sense this argument has merit: the forest will do this. But the argument has validity only to the extent that there are practicable alternatives to forest cover. But for the vast majority of our forest lands, this is not the case: the eastern forest is a natural and largely irremovable part of the landscape and its influence cannot be discounted, even for sake of argument.

Watershed Size

Forests will have a greater influence on flood peaks from small watersheds than from large. Chow (*1964*) has pointed this out for agricultural watersheds with overland flow, but the same principle holds for forested ones with subsurface flow:

> A distanct characteristic of small basins is that the effect of overland flow rather than the effect of channel flow is a dominating factor affecting the peak runoff. Also, small basins are very sensitive both to high-intensity rainfalls of short duration and to land use. On large basins, the effect of channel storage is so pronounced that such sensitivities are greatly suppressed. Therefore, a small drainage basin may be defined as one that is so small that its sensitivity to high-intensity rainfalls of short durations and to land use is not suppressed by the channel characteristics. According to this definition, the size of a small basin may be from a few acres to 1,000 acres, or even up to 100 sq. mi. The upper limit depends on the condition at which the above mentioned sensitivity becomes minimized due to the overwhelming channel-storage effect.

Hoyt and Langbein (*1955*) explained it this way: "The larger the drainage area, the longer it takes flood waters to assemble in the lower reaches of the main stem. For this reason detention of infiltrated water for any given length of time has a lesser effect upon flood runoff as the size of the basin increases."

Physiography

Forest stormflow can vary by physiographic region. For instance, for 137 watersheds in the Northeast, 100 square miles or less in area and largely forested, mean daily discharges over 10 csm. and their average annual number were significantly different by physiographic region (*Lull and Sopper 1967*):

Region	*Mean daily discharge (csm.)*	*Average annual number*
Northern New England	15	8
Southern New England	16	4
Glaciated Plateau	17	7
Ridge and Valley	16	3
Northern Piedmont	20	5
Coastal Plain	15	1

South from New Jersey along the Atlantic Coastal Plain and along the eastern Gulf Coast, the flat topography, permeable soils, and ground-water storage serve to minimize flood peaks. This is reflected in the small proportion of nation-wide flood losses that occur in these regions—1.4 and 1.5 percent—as compared with 11.3 and 28.7 percent in the more flood-prone North Atlantic and Ohio basins (*Hoyt and Langbein 1955*).

In Georgia hydrologic responses (stormflow percentages of annual rainfall) range from 3 to 18 percent for watersheds of less than 200 square miles, reflecting largely difference in natural relief and soils; only 4 percent of the annual precipitation falling in the Sand Hills and Upper Coastal Plains goes to direct runoff, about 10 percent in the Piedmont, and 15 percent in the forested mountains (*Hewlett 1967*). A map of hydrologic response for the eastern United States south of the area of significant snow cover shows definite zones of stormflow ranging from less than 4 to more than 24 percent of annual precipitation (*Woodruff and Hewlett 1969*).

Stormflow locally related to elevation can indicate storage possibilities. At Coweeta, for example, primary ridges at 5,000 feet deliver almost 18 inches of direct runoff per year while similar forest land at lower elevations delivers only 2.5 inches (*Hewlett 1967*). Storm rainfalls of 6.78 to 10.85 inches gave maximum peaks of 68 to 167 csm. above 3,000 feet, and 22 to 32 csm. below (*Hoover and Hursh 1943*).

Geology also plays a role. When Potter (*1961*) developed peak-rate prediction procedures for watersheds of 25 square miles or less east of the 105th meridian, he found it necessary

to prepare separate predictions for zones of loess and glacial till, sandstone and shale, limestone, and schist.

Flood-Control Reservoirs

Flood-control reservoirs can sharply reduce stormflow and peak flow from forested watersheds. For example, discharges from 8 forested watersheds in southern New England, four with and four without flow regulation, are as follows:

	Area (mi.²)	*Forest area (%)*	*Mean annual max. peak flow (csm.)*	*Hydrologic response (%)*
NO FLOW REGULATION				
Middle Br. Westfield (Mass.)	53	93	89	10
West Br. Westfield (Mass.)	94	94	70	10
Naugatuck (Conn.)	72	77	83	10
Leadmine (Conn.)	24	86	81	10
FLOW REGULATED				
South Br. Ashuelot (N.H.)	36	91	26	8
Priest Brook (Mass.)	19	91	19	4
East Br. Tully (Mass.)	50	92	11	5
Ringwood (N.J.)	19	93	30	6

Mean annual maximum peaks under flow regulation average about one-fourth of those from the watersheds with no regulation; comparable mean hydrologic responses are 6 and 10 percent.

Integrated Effects

Multiple correlations and regressions have been used frequently to relate meteorological, topographic, and other variables to peak discharges of storms, mean annual flood peaks, or peaks of a high recurrence interval. In 24 states in which studies have been made, the principal hydrologic factors that had significant correlation with the mean annual flood were drainage area, shape of basin, type of soil, and area of lakes (*Benson 1962a*). In New England annual peak discharges were related principally to area of drainage, main channel slope, and storage in lakes and ponds (*Benson 1962b*). In

Northeastern watersheds, highest mean daily discharges (at 0.1 percent flow durations) were related to precipitation intensity, slope, and percentage of area in swamps, but were not related to forest area (*Lull and Sopper 1967*). For small watersheds in most of the United States east of the 105th meridian Potter (*1961*) related the maximum annual peak (equaled or exceeded on an average of once in 10 years) to drainage area, precipitation, topographic indices, and drainage density. In an earlier study of 51 watersheds in the Allegheny-Cumberland Plateau, the percentage of area in cropland, pasture, or woodland had no effect on the magnitude of the 10-year peak. In regressions of peak flow versus area, many of the largest deviations above the regression had 98 percent woodland whereas those below had 50 to 60 percent cropland (*Potter 1953*).

The forest variable was considered in two of these studies (*Potter 1953; Lull and Sopper 1967*), but was not found to be significant. In all other studies, satisfactory correlations and predictions were derived without employing it. This indicated again that meteorological, topographic, and edaphic variables principally influence peak flows, and the forest variable is a confounding factor.

POTENTIALS FOR MANAGEMENT

From what has been said, potentials for reducing flood peaks or for preventing increase are slight for forest areas not recently burned or grazed severely—conservatively 95 percent of the forest area. Certain protective measures, however, can be productive on these areas. More can be done by rehabilitation of burned and grazed areas and by reforestation.

Minimize Bare Areas

Keeping to a minimum the principal sources of overland flow—logging roads and landings—is a necessary step. These areas may constitute from 10 to possibly as high as 40 percent of a watershed, depending on the type of logging and how well the roads were laid out. Careful planning and rehabilitating logging roads that are now producing overland flow are obvious ways to reduce stormflow. And keeping soil out of the channel will maintain channel capacity.

Rehabilitate Burned and Grazed Areas

About 1 million acres of forest land are burned over annually, and almost 50 million acres are grazed. As a rough estimate, perhaps ¼ million acres are burned severely enough to generate overland flow and swell flood flows; perhaps 10 million acres of forest land may be overgrazed enough to have a similar effect. In total, this may constitute 3 percent of the total forest. Scattered over 373 million acres of forest land, these areas pose no massive flood threat. Yet locally, on small watersheds, they can be source areas of tributary floods. Protection from grazing and reforestation of severely burned areas can, as has been noted, restore the role the forest normally plays in curbing flood runoff.

Reforestation

Conversion of idle eroding land can over a period of 10 to 20 years sharply reduce peak flows. The dimensions of this problem are described by the 26 million acres of nonstocked commercial forest land that need to be planted (*USDA Forest Service 1965*) that likely includes much of the 4.5 million acres of forest land that needs erosion control (*U.S. Dept. Agri. 1962*) and that is producing overland flow. This latter area amounts to about 1 percent of the total forest area, again posing no massive flood threat, but providing oppor-

tunities to reduce, if only slightly, flood peaks from tributary streams.

Forest Soil Engineering

This as yet has been given little study. Yet it may offer the best possibility of reducing flood flows by intercepting and storing subsurface flows from well-forested slopes. Only one investigator has tried it: Whipkey (*1967*) found that total subsurface flow from sprinkled plots was reduced by one-half by cutting foot-wide trenches across the plot to a depth of 4 feet and backfilling them with a heterogeneous mixture of displaced soil material.

This treatment could take full advantage of surface depression storage and detention storage in the soil where subsurface flow is otherwise so rapid that these storages do not fill even during a major storm. Disposition of the intercepted flow would depend on the nature of the site: a portion might be simply delayed on its route to the channel; other portions might take a more circuitous route to the channel or seep to underlying aquifers; and a small part might later be evaporated or transpired to the atmosphere. An increase in overland flow might also occur; efforts must be made to keep this to a minimum because it would cause erosion and do nothing to reduce peaks.

COMPARATIVE INFLUENCE OF OTHER LAND USES

Flood runoff from open land (cropland, pasture, and urban areas)—all other things including location being equal—generally exceeds that from forest land. The forest—because of its full occupancy of the area, relatively low albedo, deep root systems, and long-lasting or perennial foliage—transpires more than agricultural vegetation and thereby produces more storage opportunity and less runoff.

Most of the East was originally forest; the land cleared

for agriculture was the more tillable, deeper-soil flatland. The residual forest is on the average more mountainous and has greater precipitation, lower temperatures, steeper slopes, and shallower soils than agricultural and open lands. These characteristics promote greater runoff (*Lull and Sopper 1966*). Considering differences in location, comparison of runoff from open and forest lands loses much of its significance. Still, comparisons are of interest along the present boundaries between forest and open, where most changes in land use occur.

Cropland

In terms of hydrologic processes, interception from field crops is less than that of forest trees; infiltration rates are also lower; and storage opportunity, by reason of somewhat reduced transpiration, may also be less: consequently overland flow and storm runoff will be greater than from the forest.

The greater interception of forest trees than crops pertains more to their season of growth than to foliage-interception differences. At full growth some crops, such as dense grasses and herbs, intercept nearly as much rainfall as hardwoods in full leaf (*Kittredge 1948*). During a period of perhaps 2 to 3 summer months these crops would have about the same effect on flood-producing rainfalls as trees—namely, a minor one. For the greater part of the year cropland influences would be less.

As to overland flow, research has amply demonstrated that much more of it comes from cropland than from the forest. For example, in Mississippi over a 2-year period, Meginnis (*1935*) found that annual runoff from a plot in cotton measured 37 inches, 58 percent of the rainfall, as compared to less than ½ inch of runoff from a plot in a mature oak forest. Copley and others (*1944*) reported 5.7 inches as the average annual runoff from continuous cotton in the Piedmont of North Carolina; runoff from the woods was 0.03 inch. Plot studies of this type do not reflect amounts of over-

land flow that reach the channel; they would likely be something less than the above values.

Opportunity for soil-moisture storage on cropland is often less than on forest land because the vegetation does not fully occupy the soil and because its season of transpiration usually is much shorter.

There is also evidence that peak flows from cropland exceed those from the forest. Three examples suffice. Hobbs (*1946*) has estimated that in the Coastal Plain of New Jersey, Delaware, and Maryland peak rates of runoff expected once in 10 years from 100-acre watersheds, 50 to 75 percent in row crops, can range from 210 to 275 cfs. as compared with 28 cfs. from understocked woodland. In a study of runoff from small watersheds in western North Carolina, the average peak runoff from abandoned agricultural land was 403 csm. (flood magnitude) as compared to 84 csm. (nonflooding) from forest land (*U.S. Forest Serv. and Soil Conser. Serv. 1940*). In Wisconsin the percentages of five major rainfalls that appeared as runoff and peak flows from small watersheds in four types of cover were as follows:

Watersheds	*Runoff (percent)*	*Peak flows*	
		(in./hr.)	*(csm.)*
Corn or oats	48	1.47	949
Meadow	14	.59	381
Old field	11	.60	387
Grazed woodland	3	.12	77

No runoff was produced by forested watersheds.

These examples suggest that peak flows from cropland exceed those from forest by 5 to 10 times. From a comprehensive review of literature it has been estimated that on 1-square-mile watersheds, conversion of unmanaged cropland to forest cover may reduce yearly peaks by 30 to 90 percent (bracketing results of the above studies), and 50-year peaks by 10 to 30 percent (*Johns Hopkins Univ. 1953*).

The influence of land use on peaks has not always been so clearly demonstrated. As noted earlier, Potter (*1953*) found in a study of 51 watersheds in the Allegheny-Cumberland Plateau that the percent of area in cropland, pasture,

or woodland was not a significant variable in predicting the magnitude of the 10-year-peak.

Country-wide, there is only one study in which a forested watershed was converted to a farm and the effect on streamflow was determined. This was the Coweeta study in which a 23-acre forested mountain watershed in western North Carolina was converted to 6 acres of corn, 7 acres of pasture, and 10 acres of coppice (*Dils 1953*). Peak flows were increased manyfold. Increases in discharge for maximum 15-minute periods of precipitation were as follows:

	Stream discharge	
15-minute rainfall (in./hr.)	*Forest (csm.)*	*Farm (csm.)*
2	11	27
3	27	84
4	43	141
5	59	197

Unit storm comparisons were even more marked. A storm that produced a peak of 80 csm. before treatment resulted in a peak of over 670 csm. after mountain farming. Overland flow was largely responsible. Infiltration capacity was reduced from over 6 inches per hour to 0.6 inch in the trampled pasture and grazed cornfield.

Overland flow is not a serious problem in the one-quarter of the East where the potential for erosion is slight (*U.S. Dept. Agri. 1962*). On the other three-quarters (sloping, hilly, or mountainous), forests occupy rougher areas. Conversion of these forest lands to farmland could increase overland flow as illustrated in the Coweeta study. This, however, can be self-terminating. In the Coweeta study, corn yield, after 8 years of destructive farming, had decreased to the point where cultivation was no longer profitable. Continued successful farming requires a soil stability that to a great extent must minimize the contribution of overland flow to flood runoff.

The Coweeta study has little application to today's situation. No longer are mountain watersheds being cleared for farming; the trend, if anything, is the other way—abandon-

ing mountain farms to the forest. Nevertheless, this study gives some measure of the stabilizing influence of the forest in this particular situation.

Pasture

Heavily grazed pastures can produce as much or more flood runoff as cropland. To begin with, depending on the height of the forage, a grazed pasture will intercept no more rainfall than cropland, and often less. Overland flow may be greater, for trampling sharply reduces infiltration rates. Transpiration can be generally less than that of crops to the extent transpiring surfaces are consumed. On the other hand, pasture vegetation gives some soil protection throughout the year.

The total effect is to increase flood runoff over that produced by forest cover and often to produce more overland flow than fully vegetated cropland. Hursh (*1951*) noted that on Coweeta's mountain farm the heavily trampled pasture was the principal source of overland flow; making up 20 percent of the watershed area, it contributed 60 percent of the storm runoff. At the Bent Creek watersheds near Asheville, N.C., average maximum flow from pastured agricultural land was almost twice that of abandoned land, 785 to 403 cfs. (*U.S. Forest Serv. and Soil Conserv. Serv. 1940*). In the Wisconsin study previously cited, percent runoffs and peak flows were as follows:

Watersheds	*Runoff (percent)*	*Peak flows (in./hr.)*	*(csm.)*
Heavily grazed pasture	21	0.99	639
Lightly grazed pasture	6	.32	207
Grazed woodland	3	.12	77

As noted, there was no runoff from ungrazed woodland.

The examples given do not represent good grazing practice. As in the case of cropland, a pasture must retain sufficient moisture to permit growth and regeneration of vegetation. Overutilization of forage and overtrampling are self destructive; encouraging infiltration and minimizing over-

land flow is necessary for site preservation, providing thereby supplemental flood-control benefits. Under proper pasture management, the contribution of pasture to overland flow and flood runoff should not exceed the contribution from cropland and would probably be even less. Good pasture cover may be beneficial: in TVA's land-reclamation program on the 1,060-acre Parker Branch watershed, an increase in pasture and hayland from 23 to 60 percent of the area (reclaiming poor-quality forest and abandoned and gullied land) reduced peak flows from large summer storms by 55 percent (*TVA 1963*).

Urban and Suburban

Urbanization of a forested watershed also tends to reduce infiltration, soil-moisture storage, and evapotranspiration, and to increase overland flow and runoff. Interception may remain about the same.

For instance, a city block 1 acre in area, occupied by a 10-story building with a surface area to ground area ratio of 3:1, could intercept and store perhaps 0.06 inch of rainfall; this could amount to 16 percent of an annual rainfall of 45 inches in 120 storms, about the same amount intercepted by trees in summer. Residential areas may intercept almost the same amount (*Lull and Sopper 1969*).

In urban areas, infiltration can range from zero on pavement and roofs to rates exceeding rainfall intensities in those uncommon areas not subject to traffic of vehicles and people. Most lawns have surprisingly low infiltration capacities, for their soils have often been man-mixed, bulldozed into position, and further compacted by frequent mowing and trampling. Overland flow from areas completely paved or roofed could amount to 90 percent or more of flood-producing rainfall. In St. Louis, Horner and Flynt (*1936*) found that the average ratios of runoff rate to rainfall rate were 0.4 where 30 percent of the area was impervious, 0.65 for 50 percent impervious, and 0.8 for 72 percent impervious.

Opportunity for soil-moisture storage will also be limited

by the proportion of impermeable area. If, for instance, potential forest evapotranspiration during 3 hot summer days could provide 0.60 inch of storage opportunity, then per unit area the storage could be reduced to 0.45, 0.30, and 0.15 inch as impermeable surfaces covered ¼, ½, and ¾ of the surface area and reduced evapotranspiration in proportion. In the possible event of 2 consecutive weeks without significant precipitation, forest evapotranspiration could provide as much as 2.80 inches of storage opportunity, and the reductions for impermeable areas would be correspondingly greater.

In the eastern forest region, urbanization may increase peak flows 1.5 to 4.5 times. For example, suburban development near Washington, D.C., increased impervious area by 12 percent and flood peaks from drainage basins larger than 4 square miles by an estimated 1.8 times (*Carter 1961*). On Long Island, peak discharges with a recurrence interval of 1.15 years increased 2.3 times during a 21-year period of progressive urbanization (*Sawyer 1961*). In New Jersey, Potter (*1957*) found that the critical maximum annual peak for a 10-year recurrence interval for an urban-suburban watershed was 1.5 times greater than the peak derived from a regional prediction procedure based on watershed area and rainfall and storage indices. At Jackson, Mississippi, the mean maximum annual flood for a totally urbanized basin was about 4.5 times that from a similar but rural watershed (*Wilson 1967*).

Design peak runoff rates calculated by the rational method for urban and forest conditions give somewhat greater ratios. Peaks from urban areas 30 percent impervious were an estimated 4 times greater than peaks from flat areas of woodland on open sandy loam; for 50 percent impervious they were 5.5 times greater; and for 70 percent impervious they were 6.5 times greater (*Schwab and others 1957*).

Three factors tend to minimize the contribution of urban areas to peak flows. First, peak flows from convectional summer storms over urban areas are delivered to river channels

that are usually near their low-flow stage and often are capable of containing, without damage, the city's contribution. Second, rapid snow-melt from urban areas precludes the kind of snow accumulation that is sometimes associated with spring-season peaks from the forest. Third, because many urban areas are located at the lower end of drainage basins, their peak discharge may well precede the peak from the main basin, in effect reducing the momentary peak of the entire basin (*Lull and Sopper 1969*).

DISCUSSION

Here we wish to point out two broad interpretations derived from the foregoing material.

First, when considering the effect of forests on floods, it is necessary to establish an appropriate plane of reference to specify the condition to which the forest is compared. Reference points are necessary. Compare, for instance, the forest with a watershed paved with concrete (a hypothetical condition) or completely and permanently bared of vegetation and, for good measure, subjected to compaction. Under these circumstances one can show far-reaching differences that should leave no questions in the mind of the reader. But compare the same forest to a grassland, to another forest of different age or species, to a recently cutover forest, or to a forest subjected to infrequent light burns (wildfire or prescribed), or controlled grazing, and the comparison is not black against white, and one may be hard put to show any substantial difference.

Second, when considering only the forested condition in relation to forest-floods, the preceding material strongly suggests that perhaps good timber management *is* good watershed management. Timber-production that will provide maximum forest cover consistent with maximum yield, that will provide rapid and full regeneration after harvest, and that will minimize site deterioration by logging, grazing, or

fire, will certainly not reduce to any great extent the forests' flood-protection potential. As stated, these timber-management methods usually are compatible with good watershed management. They are in no sense, however, "hydrologic" treatments that will result in decreased (rather than maintained or merely not increased) flooding.

FORESTS AND EROSION-SEDIMENTATION

THE STABILIZING influence of the undisturbed forest on soil, and the effects of cutting, burning, grazing, and regeneration on erosion and sedimentation are truly corollary in great part to the relationship of the undisturbed forest and its treatment to overland flow, as has been described already. For erosion as considered here is simply the movement of soil particles across the soil surface by overland flow, either as sheet erosion or in the formation of rills and gullies. Those conditions that produce significant amounts of overland flow will cause erosion.

From the earlier material, it is obvious that erosion will result from overland flow when forest soil is bared and compacted by harvesting timber, when it is compacted by grazing, and when it is exposed by severe burning. It follows then that protecting the forest from destructive logging, grazing, and fire will minimize overland flow and erosion. Planting trees on abandoned eroding land, with subsequent reduction of overland flow, will sharply reduce soil loss.

It also follows that if absence of overland flow is a characteristic of the undisturbed forest, so must be the absence of erosion.

However, sedimentation—the transport of soil particles by streamflow—can still occur, for it involves sediment not only from overland flow but also from streambank erosion. Under certain conditions, it is possible to have surface erosion without sedimentation or sedimentation without surface erosion. Our discussion will be limited to suspended sediment; we will not consider problems of bedload movement (the transportation of materials—usually of larger sizes—along the bed of the channel).

To put erosion-sedimentation in proper context, types of damage should be considered. Erosion *per se* causes damages that are largely on-site. These include loss of topsoil, lower site productivity, and damage to improvements such as roads and bridges; erosion may also create eyesores that can be considered an intangible damage. Sediment in the streamflow may pollute domestic water supplies and discourage aquatic life and recreation. Sediment is also damaging when it is deposited in reservoirs, in navigation channels, in fish-spawning areas, and (in time of flood) on agricultural fields or on roads or in towns. Deposition in channels can reduce capacity and increase flooding. These are, obviously, all off-site damages.

HYDROLOGIC PROCESSES

The principal hydrologic processes associated with erosion are infiltration and the transportation of soil particles by overland flow or streamflow. Interception has some influence in those unusual situations where the mineral soil has been exposed beneath the canopy by burning or trampling, for raindrops dripping from the canopy have greater mass and kinetic energy than throughfall (*Tsukamoto 1966*) and thereby greater potential for splash erosion.

The upland forest with mineral soil fully protected by a cover of litter and humus contributes little or no sediment to the stream. In this situation erosion occurs almost entirely within the stream channel as the cutting and transporting power of streamflow detaches soil particles from channel banks and carries them downstream. In time an equilibrium develops between the quantity of streamflow and the length, width, and carrying capacity of its channel. When infrequent high flows occur, the channel is overtaxed and the flow starts to widen and lengthen it. Thus in any stream, sediment must be expected in times of extremely high flow.

Where portions of the forest floor have been disturbed and compacted by logging, grazing, and burning, infiltration is reduced and overland flow and soil erosion result. Soil loss can then become a function of soil erodibility and length and steepness of slope—all factors of importance in predicting soil loss from fallow land (*Agr. Res. Serv. 1961*).

The rainfall-erosion index (the product of total storm energy in foot-tons per acre-inch and the maximum 30-minute intensity, divided by 100) varies regionally. Approximate ranges of average annual indexes are 142 to 779 for the Southeast, 62 to 220 for the Northeast, and 64 to 261 for the North Central States. Ellison (*1949*) has shown how a bare, very permeable soil with a high infiltration capacity can be practically waterproofed by 20 minutes of rainfall.

SEDIMENT YIELDS

Country-wide average annual sediment yields for watersheds mostly under 100 square miles in area vary tremendously: by regions from 590 (Northeast and Lake States) to 16,950 tons (lower Mississippi Valley) per square mile (*Geiger 1958*). From records of 73 watersheds 0.2 to 540 square miles in area, Piest (*1964*) found sediment yields of 45 to 6,400 tons per square mile.

Forested watersheds contribute little sediment. From small hardwood-forested watersheds, the sediment carried by

streamflow during nonstorm periods amounts to about 4 to 5 tons per square mile per year; stormflow contributes another 5 to 10 tons.

For instance, streamflow from second-growth forested watersheds at the Fernow Experimental Forest in West Virginia and at the Coweeta Hydrologic Laboratory in North Carolina has an average turbidity of 2 to 5 ppm. or less for nonstorm periods (*Reinhart and others 1963; Dils 1957*); at the Hubbard Brook Experimental Watershed in New Hampshire it is less than 1 ppm. At 2 ppm., the Fernow, with an average annual runoff of 24 inches, would have a sedimentation rate of 4 tons per square mile per year; for Coweeta's 37-inch runoff, a rate of 5 tons, and 1 ppm. for Hubbard Brook's 26 inches, gives a rate of 2 tons.

We realize that turbidity measurements cannot be converted to firm weight per unit area figures; however, these data do serve to show the general magnitude of the parameters under discussion.

Stormflow turbidities from these watersheds were generally under 10 ppm., with peak values as high as 80 ppm. (equivalent to rates of 18 to 27 tons and 141 to 217 tons per square mile per year). If about one-quarter of the total flow of these watersheds is stormflow, their average sediment yield might be in the neighborhood of 10 to 15 tons per square mile per year. In terms of volume and depth of soil, a sediment loss of 10 tons is equivalent, at an estimated bulk density of 1.20, to about 270 cubic feet of material. If stream channels occupy 1 percent of the watershed, this loss would be equivalent to approximately 0.001 inch of soil eroded from the channel.

Others have reported higher yields: about 50 tons per square mile per year from forest land in the Gunpowder Falls basin of Maryland (*O'Bryan and McAvoy 1966*), 30 to 35 tons from forested areas of silicone rocks in the Swatara Creek watershed in Pennsylvania, and 50 to 60 tons from limestone areas (*Stuart and others 1967*). Annual rate of sedimentation from well-forested lands into TVA's re-

servoirs averages about 300 tons per square mile (TVA *1968*).

All these forest areas could not be classed as undisturbed, however; some roads and other disturbances almost certainly were present and contributing. Also, these watersheds are much larger than the experimental ones discussed previously, and more channel erosion may be involved. Sediment production in the range of 30 to 300 tons *per square mile* per year from forested watersheds is still well below the soil-loss tolerance limits of 1 to 5 tons *per acre* accepted for agricultural lands (*Agr. Res. Serv. 1961*).

Earth slides are also sources of major erosion and sedimentation in some localities of the Northeast. Flaccus (*1958*) charted 552 slide scars on aerial photos of the forested White Mountains of New Hampshire. Slides rarely occurred on slopes that did not at any point exceed 25 degrees, and apparently they were not appreciably affected by man's activity. There is no known way to prevent them.

Finally, the greater the proportion of a watershed in forest cover, the smaller the sediment yield. For example, in 15 sub-basins of the Potomac River with 20 to 50 percent forest cover, average annual sediment yield ranged from 90 to 500 tons per square mile; in 17 watersheds with forest cover of 60 to 90 percent, the yield ranged from 20 to 200 tons; a regression through this scatter gives the following mean yields (*Wark and Keller 1963*):

Forest cover (percent)	*Sediment yield (Tons/sq. mi./yr.)*
20	400
40	200
60	90
80	45
100	22

Thus a 5-fold increase in forest cover produced an 18-fold reduction in sediment yield.

FOREST TREATMENT AND EROSION-SEDIMENTATION

Harvesting

Erosion and sediment from areas disturbed by forest harvesting has been discussed thoroughly by Packer (*1967*) in relation to cutting, logging, and roads.

Cutting trees, *per se,* causes little or no erosion. Clearcutting mature hardwoods at Coweeta (*Hoover 1945a*) produced no overland flow and consequently no erosion. Trees cut were left where they fell, and a heavy ground cover rapidly developed. At the Hubbard Brook Experimental Forest after clearcutting and herbiciding to eliminate ground cover (a treatment for research purposes only), sedimentation increased 4-fold during the next 2 years, from 8.6 to 34 tons per square mile per year (*Pierce and others 1970*). Apparently there was no overland flow, and the additional sediment came from the stream channel.

Logging.—At the Fernow Experimental Forest, erosion and sedimentation from logging 50-year-old hardwood stands were related to the degree of soil disturbance, which in turn depended principally on care used in laying out and draining skidroads. The five degrees of logging disturbance (*Reinhart and others 1963*), a sixth and later treatment (*Hornbeck 1967*), and associated turbidity responses were as follows:

Treatment	*Vol. timber removed (pct.)*	*Max. turbidity (ppm.)*	*Percent of samples by turbidity classes*			
			0-10	*11-99*	*100-999*	*1000+*
No road plan, no drainage	86	56,000	62	20	12	6
No road plan, road drained	59	5,200	84	8	4	3
Moderate planning, drainage	31	210	96	4	—	—
Careful planning, drainage	20	25	99	1	—	—
Control (no treatment)	0	15	100	—	—	—
Careful planning, drainage	100	83	95	5	—	—

A feature of the 1963 study was the rapidity with which sedimentation diminished after logging. During logging, the watershed most greatly eroded had an average turbidity of 490 ppm.; the first year after logging this dropped to 38 ppm.; the second year to 1 ppm. (*Reinhart and others 1963*).

The later clearcutting study (*Hornbeck 1967*), in which skidroads were carefully laid out, drained, and maintained, yielded a maximum turbidity of 83 ppm., with 95 percent of the samples having turbidities between 0 and 10 ppm., demonstrating again that with care a forested watershed can be clearcut and the products removed without seriously lowering water quality. At Coweeta, ordinary logging procedures produced greater sediment: an average turbidity of 93 ppm. compared with 4 ppm. from an unlogged watershed; maximum turbidities, respectively were 7,000 and 80 ppm. (*Hoover 1952*).

Logging roads and their unprotected cuts and fills are the prime source of sediment from forested watersheds. Sediment is derived more from the roads than from tree removal. In Mississippi 5 percent of a logged area was in roads, 7 percent was in skidtrails, 2 percent was disturbed by log movement, and 1 percent was in landings (*Dickerson 1968*). Generally, in adding truck roads, skid-roads, and landings, at least 10 percent of the area is bare, and as much as 20 percent may be bare. Failure to close substandard roads after completion of logging—due to recreation or other uses—can prolong the erosion and sediment problem indefinitely.

Road cuts can produce tremendous quantities of sediment. In Georgia, highway cuts through Cecil clay with a flat slope (1:3) have produced 100 tons per acre per year, medium slope (1:1.3) 139 tons, and steep slopes (1:1) 195 tons. By aspect, northwest slopes averaged over a 3-year period 205 tons per acre, and southeast slopes 91 tons per acre. These soils losses are more than 15 times those from average steep cultivated farm lands in the Piedmont (*Diseker and Richardson 1961*).

Soil losses are less from high-quality roads. Thus, at the Fernow Experimental Forest, 530 feet of a high-order road (not to exceed 10-percent slopes except for short distances, with waterbars installed where needed) per foot of length produced 0.52 cubic feet of sediment the first year after logging; a good road (with a 20-percent slope limitation and with water bars at 2-chain intervals) 0.65 cubic feet, a fair road (no restriction on location, with water bars not closer than 2 chains) 0.70 cubic feet; and a poor road (no restriction on location and no water bars) 0.91 cubic feet (*Weitzman and Trimble 1952*).

As for skidroads, the greater their use, the greater the soil loss. Heavily used skidroads at the Fernow Forest lost 3.7 inches of soil during skidding, and lightly used roads lost 1.0 inch (*Trimble and Weitzman 1953*).

Logging and logging roads combined produce sedimentation rates that vary widely. For instance, the essential stability of glaciated soils of New England's forested mountains despite heavy cutting also has long been recognized. Cleland (*1910*) observed:

> The heterogeneous character of the till of New England is not favorable to erosion because the pebbles and boulders of the till are constantly diverting the water of the runoff and are, consequently, lessening its velocity; and also because after gullying has begun the bottom of the gully is protected from further excessive erosion by the pavement of stones derived from the till in which it was cut. Moreover, the moister climate of New England favors a rapid growth of vegetation which soon again binds the soil. In many places in the Berkshires and in Vermont and New Hampshire mountain slopes which rise from 700 to 1,000 feet in one quarter of a mile have been several times stripped of their forest growth with little, though doubtless some, injury to the soil.

Elsewhere the situation can be quite different. In the southern Appalachians, on clay soils at Coweeta, roads and logging produced maximum sedimentation of 7,000 ppm. as compared to 80 ppm. for an undisturbed area. Turbidity from the logged area averaged 93 ppm. as compared with 4 ppm. from the check area. Repeated measurements of road cross-sections showed that in 4 years the 2.3 miles of road lost

6,850 cubic yards of soil (*Hoover 1952*). This impaired the water quality of the stream draining a 1,880-acre watershed to the extent that the timber returns were judged less than costs that might be required to treat the water (*Hursh 1951*).

There is considerable evidence, however, that careful logging minimizes sediment production. On an 800-acre timber sale on the Chattahoochee National Forest in Georgia, careful logging yielded an average sediment content of 5 ppm. as compared to 4 ppm. from an unlogged watershed (*Black and Clark 1958*). Likewise, on the Waynesville, N.C., municipal watershed of 8,000 acres, 13 million board feet of timber were harvested in 10 years of logging, and 50 miles of road were built, all without damaging the water resource (*Vogenberger and Curry 1959*).

Burning

Based on earlier considerations, the occasional wildfire that will not produce overland flow will not cause erosion. Nor will infrequent prescribed burning. Thus, summer-prescribed fires in Georgia's lower Piedmont, which killed 86 percent of the understory hardwood stems and provided for successful regeneration of pine, had a negligible effect on soil movement. "Almost all of the decomposed litter was left to protect the soil; even some of the partially decomposed litter remained unburned. The top layer of mineral soil also has organic matter incorporated in it and is receptive to rainfall absorption" (*Brender and Cooper 1968*).

Repeated burnings that remove litter and humus can produce substantial amounts of overland flow from upland areas and, consequently, erosion and sediment. In the North Carolina study by Copley and others (*1944*), the woodland plot burned twice annually lost 0.01 ton of soil per acre the first year, and 0.03 the next year; by the third year the loss was 1.04 tons and by the 5th year 3.90 tons; the next 4 years the loss averaged about 5 tons per acre, a substantial amount though still only about one-fifth the loss from cotton

and corn plots. A loss of 5 tons of soil per acre represents a removal of about 0.03 inch of soil annually. The unburned plot consistently lost only 0.01 ton per acre per year.

In the Mississippi study also considered earlier, erosion from a scrub oak plot, typical of areas subject to severe cutting and annual fires, amounted to 0.33 ton per acre per year as compared to 0.02 ton from a mature oak forest. Conditions under the scrub oak were somewhat better than those in the North Carolina study; small quantities of litter were present although the mineral soil was exposed in many places (*Meginnis 1935*).

Grazing

The few data on erosion from woodland grazing suggest that its initiation may be slow and its magnitude not great. In one of three studies on this subject, a grazed hardwood watershed in Wisconsin lost soil at the rate of 0.14 ton per acre per year, whereas no soil was lost from a protected woodland watershed (*Hays and others 1949*). In another Wisconsin study, maximum rates of sedimentation from grazed and ungrazed small watersheds were 55,900 and 100 ppm. respectively.

Woodland grazing of a Coweeta watershed had little or no effect on sediment until overland flow finally made its way to the stream channel in the ninth year of grazing. Shortly thereafter, the maximum turbidity in one storm was 108 ppm. as compared to 30 ppm. from an adjacent ungrazed forested watershed (*Johnson 1952*). The delayed effect was explained by Hursh (*1951*) as follows:

> The reason is that the forest litter collected in small ravines and depressions as it was blown by the wind from the sheet-eroded trampled areas. This litter filtered out the silt, enabling clear water to go into the soil before it reached the main watercourse. As the sheet-eroding and trampled areas increased in size, there was a gradual increase in the amount of storm water accumulation on the soil surface. As the amount of surface water increased, it finally gained sufficienct force to carry away the litter plugs along natural drainage lines and develop uninterrupted drainage channels to the main stream.

Very likely, complete and rapid utilization of forage from woodland could well result in removal of the livestock before serious erosion begins (supplemental feeding of livestock was found necessary long before completion of the Coweeta study).

Most studies of woodland grazing strongly suggest that concurrent production of timber and forage should not be attempted. However, there are areas, particularly in the Coastal Plain pinelands of the South, where this multiple use is feasible; under proper management, grazing need not result in excessive erosion or other damage.

Regeneration

Planting trees to stop erosion is not always necessary. Old fields may support sufficient invading vegetation to stabilize soil without tree planting. Abandoned fields and pastures in central Pennsylvania lost no soil during infiltrometer runs with rainfall intensities up to 3 inches per hour (*Alderfer and Bramble 1942*). In West Virginia, farmlands abandoned for two decades have healed naturally to the extent they produce only slightly higher turbidities than undisturbed forest land (*Hornbeck and Troendle 1969*). In the New York study referred to earlier, trees were planted in abandoned fields that had already developed a heavy cover of woods and brush (*Schneider and Ayer 1961*). Erosion and sedimentation were not considered and, presumably, were absent even before planting.

In contrast, planting about one-third of the severely eroded 1,715-acre White Hollow watershed in Tennessee reduced the sediment load for the average storm from 7.3 tons in 1935-36 to 0.3 ton in 1954-55, a reduction of 96 percent. Reduction each year to 1955 averaged about 15 percent of the previous year's sediment load (*TVA 1961*). Planting two-thirds of the Pine Tree Branch watershed in Tennessee reduced the sediment load from 24.3 tons per acre in 1942-45, to 7.6 in 1946-50, to 2.2 in 1951-55, and 1.1 in 1956-60, an overall reduction of 96 percent (*TVA 1962*). Evaluation

of results from both of these watersheds is complicated by the fact that other erosion-control measures, such as installation of check dams, were also applied.

Similarly, in northern Mississippi, planting loblolly pine sharply reduced sedimentation. Rates of loss were as follows:

Land use	*Mean tons/acre*	*Range tons/acre*
Pine plantation (22 yrs. old)	0.02	0.00 to 0.08
Mature pine hardwoods	.02	.01 to .04
Abandoned fields	.13	.01 to .54
Cultivated lands	21.75	3.28 to 43.06

The pines had been planted on fields from which erosion had removed an estimated 2 feet of the surface and had cut gullies 5 feet below the level of the remaining soil (*Ursic and Dendy 1965*).

At Coshocton, Ohio, pine and a few black locust seedlings were planted on abandoned eroded cropland comprising about 70 percent of a 44-acre experimental watershed. Thirty percent of the area was in mixed hardwoods. In 6 years a rather complete ground cover had been established, sheet erosion practically ceased, and smaller gullies were stabilized (*Harrold 1960*).

POTENTIALS FOR MANAGEMENT

Sedimentation ranges from 10 to 15 tons per square mile per year for small forested watersheds to 30 to 90 tons for larger watersheds. It is greater on about 1 percent, or 4.5 million acres, of the forest land in the East that needs erosion-control treatment. Almost one-half of this area is in the Southeast (largely in Alabama, Georgia, and Mississippi) and over one-fourth in the Central States (mostly Kentucky and Missouri) (*U.S. Dept. Agr. 1962*).

The magnitude of the erosion control problem on forest lands is governed by a number of considerations: soil dis-

turbance, topography, and stoniness. The degree of soil disturbance is the prime factor. As is surely evident by now, an undisturbed forest soil presupposes no erosion. With few exceptions, erosion will result where the forest soil is exposed by logging, fire, or grazing.

The potential erosion from disturbed areas depends partly upon topography. It is low on the 26 percent of forest land (non-Federal) in the East that is so level or wet to preclude erosion. It also depends on stoniness of soils. In hilly and mountainous areas, with greater erosion potential, losses may be reduced where stony soils quickly slow the erosion process by forming an erosion pavement. An example is the reduction in turbidity of the clearcut watershed at the Fernow Experimental Forest; during the logging operation turbidity averaged 490 ppm.; the first year after, it was 38 ppm.; and the second year after, it was 1 ppm. (*Reinhart and others 1963*). This rapid recovery is typical of many forested areas, and it suggests why they continue to produce high-quality water despite repeated cuttings.

Self-healing, however, becomes effective only after considerable damage to water quality has been done. Hoover (*1945b*) has pointed out that a short stretch of logging road can contribute more sediment to a stream draining a forested watershed than occasional patches of steep land in cultivated crops.

When soils are not stony, erosion can continue for some time as at Coweeta, where for several years clay subsoil from skid trails and roads continued to move into streams after every storm. Three years after the eroding areas where stabilized by seeding, the water was still slightly murky during the normal flows. (*Personal communication from John D. Hewlett, Coweeta Hydrologic Laboratory, Jan. 8, 1963*).

Erosion control begins with planning. Considering that as much as 90 percent of the sediment produced by erosion on timber-sale areas comes from roads (*Packer and Christensen 1964*), planning begins with those measures that will hold

road mileage to a minimum. This involves selection of a logging method and road location.

Advance planning of road location can reduce both road area and gradient. Logger's-choice road systems (unplanned) at the Fernow Experimental Forest occupied 4.8 to 7.0 percent of the area, with grades of 14 to 24 percent; a planned system occupied 2.5 to 4.6 percent, with grades of 9 to 15 percent. By careful planning the area in skidroads can be reduced 40 percent (*Mitchell and Trimble 1959*).

Slope-length relationships and intensity of use can govern road location. Thus, though a 4-percent grade might limit drainage problems, an 8-percent grade would require one-half the road length and might not be a hardship on modern vehicles. Time of travel would also be shorter (*Byrnes 1962*). As the end of the road is approached, soil disturbance may be reduced by lowering road standards to meet the expected reduction in road use (*Banta 1963*).

Control of road erosion requires, besides proper location, the drainage necessary to prevent overland flow from developing a depth and velocity that would seriously erode the road surface, and also preventing road runoff from reaching the stream channel downhill. According to Packer and Christensen (*1964*), surfaces of secondary logging roads deteriorate rapidly when rills are allowed to erode deeper than 1 inch. Therefore the distances that water flows down-road before eroding 1-inch rills should determine the spacings of cross drains. Next, the distance that sediment can move downslope from outlets of cross drains determines the widths of protective strips needed to keep sediment out of the stream channel.

Spacing of cross-drains and width of protective strips have been determined largely by slope. For instance, for municipal watersheds Trimble (*1959*) has recommended that maximum grades on truck roads or heavily used skid trails should be less than 10 percent except for very short stretches. Such roads can be drained adequately by spacing cross-drains according to a rule-of-thumb: divide 1,000 feet

by the percentage road grade. With a 5-percent grade, the drains would be 200 feet apart; at 10-percent, 100 feet.

Minimum distance of road to stream was determined in the White Mountains of New Hampshire to be 25 feet plus 2 feet for each percent of slope to the stream. Thus, on a 20-percent slope the road should be located about 65 feet from the stream (*Trimble and Sartz 1957*). Water-spreading devices below the drainage outlet would permit narrower strips.

Planning also includes locating cutting areas, as well as landings and skid trails, in advance of logging. Landings should be located to minimize yarding across streams (*Dunford 1962*).

With all this, the attitude of the logger must be taken into account. Dunford (*1962*) has noted this:

> In the final analysis, protection against erosion and stream damage is dependent upon the attitudes of the forest user. If there is a genuine desire to prevent erosion and protect streamflow, measures can usually be effectively applied. Many of them can be accomplished at little extra expense. It is important to apply needed measures at the right time and in the right place.

OTHER LAND USES

As overland flow increases, erosion and sediment yield increase even more than in proportion. This is because erosion depends upon velocity as well as volume of overland flow; and, other things being equal, the greater the volume, the greater the velocity. Land-use effects are particularly striking when sedimentation from a forested area (where subsurface flow accounts for the stormflow) is compared with that from cropland where overland flow, with its burden of sediment, comprises stormflow. For instance, in the Wisconsin study previously cited, maximum sedimentation rates from several land uses were as follows:

Watershed	*Suspended sediment (ppm.)*
Clean tilled	238,000
Heavily grazed pastures	82,000
Lightly grazed pastures	13,000
Heavily grazed woodland	55,900
Alfalfa meadow	19,800
Logged forest	3,600
Old field	300
Undisturbed forest	100

Cropland

Average annual sediment yield from rural watersheds occupied by forest and cropland has been estimated to range from 55 to 250 tons per square mile for various physiographic zones of a Pennsylvania watershed (*Stuart and others 1967*) and 15 to 900 tons for a representative selection of rural watersheds in Maryland (*Wolman and Schick 1967*). Estimated sediment yield from farmland in the Gunpowder Falls basin of Maryland ranged from 1,000 to 5,000 tons per square mile per year (*O'Bryan and McAvoy 1966*). In the TVA reservoirs, annual rates of sedimentation from watersheds with large amounts of open and cultivated land are 600 to 1100 tons per square mile (*TVA 1968*). In inches of depth, sediment yields ranging from 50 to 5,000 tons per square mile are equivalent to 0.0006 and 0.06 inch, respectively; if we assume that all erosion was from the channel occupying 1 percent of the area, the loss would be 0.06 and 6.0 inches depth.

Other things being equal, the greater the proportion of cropland in a watershed, the greater the sediment yield. In the Potomac River study already mentioned, average annual sediment yield of basins with 5 to 25 percent cropland ranged from 20 to 200 tons per square mile, and for those with 25 to 50 percent, from 100 to 500 tons; a regression gave the following amounts (*Wark and Keller 1963*):

Cropland (percent)	*Sediment yield (tons/mi²/yr.)*
10	80
20	120
30	150
40	200
50	250

In the only study in which a forested watershed (at Coweeta) was converted to farmland, the average soil loss per acre per year increased from 154 pounds at the beginning of the study to an average of 1,993 pounds during the 10 years of farming. Sediment yields were extremely variable: during one 3-month period of above-normal precipitation nearly one ton of sediment per day was discharged from the 23-acre watershed. During the final year of treatment the yield per acre was 936 pounds (*Dils 1953*).

At the Central Piedmont Experiment Station in North Carolina, soil loss per acre from a 6-acre wooded watershed averaged 0.05 tons per year and from a watershed cultivated to different crops 9.5 tons per year. Losses ranged from 31 tons in one year when in cotton to 0.03 tons when in lespedeza (*Copley and others 1944*). In northern Mississippi average annual soil losses from small forested watersheds on loessial soils were 0.02 tons per acre per year and from cultivated watersheds 22 tons (*Ursic and Dendy 1965*).

Pasture

The substantial contribution of pasture to flood runoff, as described earlier, from the few data available does not seem to be matched by a proportionate soil loss. For instance, on Coweeta's mountain farm the heavily trampled pasture contributed 60 percent of the storm runoff but less than one-third of the soil loss (*Hursh 1951; Dils 1953*).

In Wisconsin no soil was lost from a pasture watershed from which 4.65 percent of annual precipitation appeared as runoff. A grazed woodland with less runoff—1.16 percent—lost 0.14 tons of soil per acre per year (*Hays and others 1949*).

In the north Mississippi study just noted (*Ursic and Dendy 1965*) soil loss from a small pasture watershed averaged 1.6 tons per acre per year, much greater than the 0.02-ton loss from the forest, but much less than the 22-ton loss from cropland. Likely the combined influence of year-round residual vegetation in a pasture plus the compaction of the soil gives the soil a stability in the face of overland flow that is not realized in cropland.

Very few studies have compared sediment production from forested and pastured watersheds in the East. This may be due to the relative unimportance of sediment yield from pasture lands. With little watershed evidence of the pasture-effect, Colman (*1953*) could still write that:

> In the East, pasture studies in a number of states have all led to the conclusion that increasing intensity of grazing causes decreased ground-cover density and increased soil compaction. Both lead to increased susceptibility of the soil to surface flow during storms. The sod-grasses and legumes that make up most of the forage in the humid part of the country protect the soil well against erosion, if grazing is not too heavy.

Urban and Suburban

Urban land may produce either higher or lower erosion and sediment than farm or forest. For instance sediment from urban and suburban land of the Gunpowder Falls basin was 50 to 100 tons per square mile per year as compared to about 50 tons from forest land and 1,000 to 5,000 tons from farmland (*O'Bryan and McAvoy 1966*). On any one area, probably nothing stabilizes the underlying soil as well as a substantial covering of asphalt or concrete; overland flow from these areas can erode unprotected soils downslope.

The stabilizing effect of urban development (though conservation measures also contributed) is illustrated by the reduction in sedimentation of Baltimore's Loch Raven Reservoir from an average annual rate of 185 acre-feet in 1914-43 to 41 acre-feet in 1943-61, a reduction of over 75 percent. Conditions at their worst were aptly described by Abel Wol-

man (*1968*): "In Baltimore, in my youth . . . in some instances, water was squeezed out of the mud, instead of the sediment being removed from the water."

Sediment produced from urban areas comes largely from road and channel banks and from areas where construction is in progress. Topography appears to have considerable influence: in New Jersey moderately heavily urbanized flatland yielded 25 to 100 tons of sediment per square mile per year as compared to 75 to 500 tons from a heavily urbanized upland area (*Anderson and McCall 1968*).

Urban areas under construction can become bountiful sources of sediment, especially where modern earth-moving equipment reshapes the land into building lots, and the soil remains unprotected. According to Holeman and Geiger (*1959*) such areas may remain bare for about 3 months for single-dwelling construction, and large housing and apartment developments may expose soil more than a year. Building permits issued in Baltimore County indicated that 40 percent of the sites were open for more than 9 months and 25 percent were open for more than 1 year (*Wolman and Schick 1967*).

A notorious example of construction-erosion is the Lake Barcroft area near Washington, D.C., where 25,000 tons of sediment were deposited for each square mile of residential construction (*Guy and Ferguson, 1962*). In another housing project in the same area, the sediment load for the construction period averaged 121,000 tons per square mile (*Guy 1965*). Over the project area (20.5 acres) this would be equivalent to removal of about 1.1 inch depth of soil.

A survey of the Detroit metropolitan area in 1968 revealed that 2.1 percent—about 16,000 acres—supported construction activity. Average annual erosion rate was 69 tons per acre (44,000 tons per square mile) giving a total annual erosion of over a million tons. Erosion from the small area of construction produced about the same amount of eroded material as erosion from the other 97.9 percent of the area (*Thompson 1970*).

For the metropolitan Washington area, sediment discharge to streams from urbanizing rural areas amounts to 10 tons for each person added to the city. Over a larger area, metropolitan Baltimore County, sediment production was on the order of 1,800 tons per 1,000 increase in population, and for Prince Georges County near Washington, a yield of 700 tons per 1,000 increase (*Wolman and Schick 1967*). As noted, sedimentation rates of urban and suburban areas may drop to 50 to 100 tons per square mile once construction is completed.

DISCUSSION

Most of the really steep land originally placed under cultivation (at the start of the forest-flood controversy) has by now become forest or pasture. Jokes like the one about using a ladder in the cornfield to get up to the next row are not now as common or as relevant as they were 30 years ago. Much of the area still in cultivation is benefiting from soil-conservation practices. And urbanization, once the conversion is made, may also serve to reduce the erosion potential.

The Chattahoochee River provides an example of this trend (*Albert and Spector 1955*). Average annual turbidity at Atlanta, Georgia, declined steadily over a 25-year period from a high of 400 ppm. in 1934 to a low of 69 ppm. in 1952; runoff volume did not show a trend. Improvement was attributed to the conservation program on this 928,000-acre watershed, including: a reduction (of 40 percent) in cropland acreage, forest-fire protection, tree-planting, and farm soil-conservation practices. The trend already cited for the Loch Raven Reservoir (*Holeman 1965*), due to land-use change and conservation measures, is another example.

SUMMARY AND CONCLUSIONS

IN LIGHT of the foregoing discussion of the influences of forest and other land uses, and in light of the total land-use situation in the eastern forest region, certain concepts that help define and clarify the forest-flood and forest-erosion relationships may be stated.

LAND-USE CONDITIONS

To begin, these are the land-use conditions that we consider pertinent:

1. Forests occupy 48 percent of the eastern forest region, a percentage larger than that for any other land-use.
2. Three-quarters of the eastern forest region is characterized by hills and mountains which, because of their elevation, high precipitation, steep slopes, and restricted storage, are the principal sources of flood runoff. Forests occupy 61 percent of these lands, including the highest, steepest, and rockiest.
3. Present and predicted land-use trends indicate that almost all of this flood-producing area will continue in forest cover.
4. About 1 percent of the forest area in the East needs erosion-cotrol treatment; about one-half of this area is in the Southeast and about one-third is in the Central States.

5. Forest grazing is no longer an important land-use source of overland flow, flood runoff, and erosion in the Northeastern and Middle Atlantic States. In the South, forest grazing has proved successful when limitations in carrying capacity are recognized, and when combined with supplemental feeding or integrated with improved pasture.
6. Substantial reductions in number and frequency of wildfires and of area burned have served to diminish greatly the hydrologic importance of fire in the East.

HYDROLOGY

Next, some of the most pertinent hydrologic facts of life as we see them. First, about floods:

1. The forest, because of its full occupancy, provides for any site a maximum opportunity for controlling runoff from flood-producing rainfalls; even so, the forest cannot prevent floods.
2. Interception, infiltration, and soil-moisture storage opportunity are the principal ways in which forest cover diminishes the discharge from flood-producing storms.
3. Infiltration capacities of the forest floor are almost everywhere greater than rainfall intensities. The Horton theory of excess rainfall as the source of overland flow and flood runoff does not apply in the eastern forest.
4. Forests, by preventing erosion and sedimentation, help to maintain stream-channel capacity so that they can carry storm flows with a minimum of flooding.
5. In the generally humid East, soil-moisture storage opportunity is influenced more by rate and duration of drying and drainage than by soil-moisture storage capacity.

6. The principal source of flood runoff delivered to the channels in forested watersheds is subsurface flow that moves rapidly downslope through the permeable forest floor and topsoil.
7. Record flood discharges from forested mountain watersheds result from precipitation, soil, topography, and geology rather than the condition of their cover.
8. Changing rates of snow melt by manipulating forest cover may either increase or decrease snow-melt peaks, depending on watershed conditions, including land-use diversification, and weather sequences.
9. Frost, concrete or otherwise, does not play an important role in the generation of flood peaks from forests.
10. Clearcut or burned, forest land in the East remains bare for but a brief period before rapid growth reclothes the site with sprouts, tree seedlings, and herbaceous plants.
11. Most forest fires in the East result in only slight or short-term exposure of mineral soil to rainfall impact; consequently their effect on flood runoff and erosion is slight.
12. The forest's influence on storm-flows is strongly modified by the size of the flow-producing storm, the area of the watershed as it affects channel storage capacity, and the season of storm occurrence.

Second, about erosion-sedimentation:

1. Erosion from the undisturbed forest occurs almost entirely within the stream channel as discharge detaches soil particles and carries them downstream; the upland forest, between the channels, contributes little or no sediment to the stream.
2. Erosion is not caused by cutting of trees, *per se,* but by the soil disturbance that usually accompanies or follows cutting.
3. In hilly and mountainous areas with great erosion potential, soil losses may be reduced where stony soils quickly slow the erosion process by forming an erosion pavement.

4. In woodland grazing, the initiation of erosion may be slow, and its magnitude under present-day conditions is not great.
5. Other things being equal, the greater the proportion of cropland in a watershed, the greater the sediment yield.
6. When pasture-grazing is not too heavy, the residual vegetation protects the soil well against erosion.

INFERENCES

From the foregoing, we make the following inferences:

1. Except for limited areas of land-use change, it is pointless to belabor the hypothetical effects of permanently clearing flood-producing, forested, mountain watersheds because all indications are that land-use trends are in the opposite direction.
2. Planting abandoned land can appreciably reduce peak flows under some conditions; under other conditions, volunteer vegetation may accomplish about as much even though it may be silviculturally less desirable.
3. Where plantations are established on eroding land, erosion will eventually cease as litter and humus begin to protect the soil and as overland flow is stopped.
4. Clearcutting without serious disturbance of the forest floor does not drastically reduce infiltration rates and does not result in overland flow. It does result in reduced soil-moisture storage opportunity at some times; provided only a small proportion of the watershed is clearcut at any one time, increases in peak flow and flood runoff will not be large enough to be important.
5. With care, a forested watershed can be clearcut and the products can be removed without seriously lowering water quality.
6. Forest stands that have not been severely burned or grazed are performing their hydrologic function; there appears to be little opportunity for flood reduction

through management methods, except by limiting the extent of heavy cutting.

7. The potential for reducing flood damages through forestry is greatest where forests can be established on nonforest lands that produce substantial amounts of overland flow.

GENERAL CONCLUSIONS

From our review of the influence of the Eastern forest on floods, we draw the following general conclusions:

- The forest is the best of all possible natural cover for minimizing overland flow, runoff, and erosion.
- With reasonable care, the forest can be cut with little detriment to its site-protective capability.
- Under sustained-yield programs of forest management and with the great diversity in age classes of private forest ownership, the extent of forest cutting offers no flood threat.
- Current levels of forest burning and woodland grazing are not sufficiently widespread to generate damaging floods.
- The flood-reduction role of the forest can be realized through continued fire protection and careful logging, and can be enhanced by reforestation of abandoned land.
- Present trends in land use suggest no widespread deforestation of forested flood-source headwaters in the foreseeable future.

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